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Chile

CONTRIBUCION DE LA CORPORACION DE FOMENTO DE LA PRODUCCION AL DESARROLLO DEL AGUA SUBTERRANEA EN CHILE

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TEXTO

1.- Antecedentes generales.

Con una superficie de 742.000 Kms2, excluído en territorio antártico, Chile se extiende desde los 17°12' a los 56°32' de latitud sur, entre el Océano Pacífico y la Cordillera de los Andes, con una longitud de 4.300 Kms. y un ancho medio de 188 Kms. (Fig.I).

Su gran variedad de clima que va desde el árido desierto del Norte hasta el riguroso del sur queda demostrado en el siguiente cuadro de distribución anual promedio de precipitaciones.

Localidad	precipitación en mms.	Localidad	precipitación en mms.
Arica	0	Talca	742
Antofagasta	0	Chillán	1033
Calama	0	Los Angeles	1285
Copiapó	28	Temuco	1345
La Serena	110	Osorno	1330
Illapel	215	Puerto Montt	1960
Los Andes	304	Aysen	2868
Santiago	360	Punta Arenas	436

Esta diferencia de clima permite dividir el país en las siguientes zonas geográficas:

Zona geográfica	Superficie zona	Latitud
Norte Grande	178.000 Kms2	18° - 26°
Norte Chico	120.000 Kms2	26° - 32°
Chile Central	147.000 Kms2	32° - 39°
Sur Chico	72.000 Kms2	39° - 45°

Zona geográfica	Superficie zona	Latitud
Sur Grande	225.000 Kms2	45° - 56°

Esta división corresponde también a una clasificación hidrológica de las regiones en cuanto a los períodos de riego necesarios para la producción agrícola, en conformidad al siguiente detalle:

Zona	Períodos de riego (anual)
Norte Grande	Todo el año
Norte Chico	10 meses
Chile Central	9 meses al Norte y 4 meses al Sur
Sur Chico	1 a 2 meses
Sur Grande	No se necesita

De una superficie de 74 millones de Hás., 22 millones no son aptas para la agricultura, 21 millones están cubiertas de bosques y de las 31 millones restantes, sólo 11 millones de Hás. pueden considerarse superficie cultivable, de las cuales 7 millones de Hás. necesitan riego.

Actualmente se cultivan 6.8 millones de Hás. de suelos agrícolas de los cuales cuentan con riego 1.4 millones de Hás.

El Plan Nacional de Desarrollo Económico de Chile para el Decenio 1961-1970, consulta un aumento de 400.000 Hás. de riego y un mejoramiento en sus actuales condiciones de regadío de 600.000 Hás.

La Minería y especialmente la Industria continúan creciendo a un ritmo seguro y las necesidades de agua irán en aumento, especialmente por el hecho que muchas de ellas serán grandes consumidoras de agua (fábricas de celulosa, papel, azúcar de remolacha, productos químicos, ampliación de las refinerías de petróleo y acero).

Finalmente si estudiamos el crecimiento demográfico de Chile tenemos el siguiente cuadro:

Año	Población	Porcentaje anual de crecimiento
1885	2.492.000	1.16%
1907	3.213.000	1.34
1930	4.365.000	1.68
1952	6.295.000	2.50
1957	7.121.000	2.20

Esto demuestra las repercusiones que en materia de suministro de agua, necesidades alimenticias, demanda de energía y crecimiento industrial, tendrá esta tasa de crecimiento que supondremos se mantendrá en un 2.2% anual.

Para todas estas necesidades, el país ha utilizado fundamentalmente sus recursos de aguas superficiales, los que, en muchas regiones, no son suficientes para las actuales necesidades en los diferentes campos económicos.

Es por esto que se ha necesitado ir a la búsqueda, estudio y aprovechamiento de las aguas subterráneas que escurren en las diferentes hoyas hidrográficas del país.

2.- El desarrollo del agua subterránea.

Ya en el siglo pasado, en la desértica zona norte, se construyeron innumerables piques a mano destinados a obtener agua principalmente para el abastecimiento de Oficinas Salitreras cuya explotación intensiva se mantuvo hasta la pasada primera guerra mundial.

De acuerdo a registros especiales, en 1920 existían en la Pampa del Tamarugal alrededor de 130 piques a mano de profundidades desde 2 hasta 80 metros que abastecían 71 oficinas salitreras, con un gasto en conjunto de 150 lts/seg.

Las primeras perforaciones hechas en el país utilizando máquinas especiales fueron ejecutadas por el Ministerio de Obras Públicas a través de sus Direcciones de Riego y Obras Sanitarias, organismos que realizaban estas obras ya sea con fines de ubicación de nuevos recursos de agua, especialmente en la zona Norte del país, como para abastecer de agua potable a algunas ciudades y poblaciones.

Sin embargo, hasta 1945 esas investigaciones habían sido esporádicas dentro del territorio chileno. En ese año la Corporación de Fomento de la Producción (CORFO) acordó en principio la creación de la Sección Aguas Subterráneas, para lo cual solicitó al Gobierno de los E.E.U.U. la venida al país de una Misión de Trabajo que permitiera conocer bajo el punto de vista hidrogeológico, las zonas más favorables del país con el fin de orientar los sondajes futuros. En Mayo de 1946 llegó a Chile la Misión Taylor integrada por los Sres. George C. Taylor y Spencer Nye del USGS. El trabajo de reconocimiento fué completado en 1948 y la enorme cantidad de información acumulada que comprende fundamentalmente la zona Arica-Santiago, fué publicada posteriormente por la Corfo.

Posteriormente en 1955, Chile firmó un Convenio con el Gobierno de EE.UU. para tener asistencia técnica en el campo de las aguas subterráneas. Fruto de este Acuerdo fué la llegada al país de un grupo de hidrogeólogos del USGS que desde esa fecha hasta el momento están trabajando en esta especialidad en conjunto con diversos geólogos chilenos en la Sub-sección de Agua Subterránea del Instituto de Investigaciones Geológicas organismo creado en 1958 por Corfo y el Departamento del Cobre. Los estudios científicos que allí se realizan se desarrollan en estrecha relación con la labor que realiza la Sección Aguas Subterráneas de Corfo.

3.- Labor realizada por Corfo.

Finalizada la etapa de reconocimiento efectuada por la Misión Taylor en 1948, Corfo adquirió la primera de sus máquinas perforadoras del tipo a percusión.

En la actualidad se cuenta con 17 equipos perforadores, 16 de ellos a percusión y uno del sistema combinado percusión-rotación.

Las características especiales del relleno del subsuelo en la gran mayoría de los valles de las regiones del Norte Chico, Valle Central y Sur Chico, regiones en las cuales se han contruído la mayoría de los pozos ejecutados, hace necesario el empleo del sistema de perforación a percusión, razón por la que Corfo había utilizado hasta la fecha solo maquinaria de este tipo.

El mayor conocimiento de algunas regiones en la Zona Norte y parte de la zona Sur de nuestro territorio han hecho ver la conveniencia de utilizar en determinados sectores, el sistema a rotación por lo que se ha incorporado últimamente un equipo de combinación que permite tener avances más eficientes.

Como política general, se ha tratado que la gran mayoría de las perforaciones que se realicen con fines de estudio puedan tener posteriormente un aprovechamiento inmediato. De esa manera se ha conseguido, además de obtener el máximo de información que arroja cada perforación, que ésta pueda servir para satisfacer usos agrícolas, industriales o de agua potable.

En trece años de labor, hasta Enero de 1962, Corfo ha completado la ejecución de 387 perforaciones conforme a la siguiente distribución de acuerdo al uso del agua.

Uso del agua	N° de pozos construídos	Rendimiento en lts/seg	Total de metros perforados
Agrícola	207	15.656	16.697,96
Industrial	68	3.827	4.522,34
Agua Potable	27	1.440	1.884,91
Reconocimiento	85	648	5.655,91
T O T A L E S	387	21.571	28.761,12

Las perforaciones han dado como resultados más significativos, además de la información obtenida, los siguientes:

1) La incorporación potencial de una nueva superficie de riego de 20.000 Hás.
2) La solución de los problemas de abastecimiento de agua a 68 industrias.
3) El abastecimiento de agua potable a una población estimada de 300.000 personas.

En la Fig. II se muestra la distribución anual y los rendimientos de las obras ejecutadas en los 13 años mencionados.

4.- Algunos resultados hidrogeológicos de los estudios realizados.

Los programas exploratorios efectuados en Chile, con el objeto de obtener información sobre las posibilidades de aguas subterráneas, han permitido llegar a un conocimiento general en esta materia. Gran parte de las áreas pueden ser clasificadas desde este punto de vista como de buenas, regulares o malas.

Los valles cuyas hoyas hidrográficas incluyen áreas con lluvias o nevazones anuales, tales como el Altiplano del Norte, o la zona pre-cordillerana sur, generalmente producen agua de los depósitos recientes de arena y ripio que forman el relleno parcial de los valles.

En el Norte de Chile las formaciones geológicas circundantes generalmente no transmiten ni contienen agua, quedando las zonas de recarga limitadas sólo a los valles mismos.

El conocimiento de las fuentes de aguas subterráneas se transforma entonces en un estudio del régimen total de aguas a saber: El flujo superficial, el escurrimiento subterráneo y las interrelaciones entre ambos; la evapotranspiración y la recarga producida por la filtración de agua de regadío.

Se está efectuando un estudio en el valle de Copiapó que es típico entre los valles del norte. (Fig.I). Se han perforado pozos de estudio para determinar las propiedades hidrológicas de los acuíferos. Se han hecho investigaciones, que incluyen pruebas de drenaje, para determinar las pérdidas y recuperaciones de los ríos a lo largo de su curso; también el volumen de recarga debido al agua de

regadío ha sido objeto de un estudio, lo que ha permitido una planificación científica de la totalidad de los recursos hidrológicos. Estas experiencias son naturalmente ejecutadas en forma paralela con los cambios que se efectúan tanto en los cultivos como en los métodos de riego de tal modo de asegurar una utilización racional de las aguas.

Un estudio similar se está llevando a cabo en el valle de Azapa, en el extremo norte de Chile (Fig.I), habiéndose además efectuado perforaciones exploratorias en la terraza Pleistocénica que se extiende al norte de la desembocadura del valle de Azapa. Se ha encontrado agua subterránea con características artesianas en estos depósitos y mediante métodos geológicos e hidrológicos se está actualmente tratando de determinar la procedencia y el posible volumen de recarga. El futuro desarrollo de la ciudad de Arica depende hasta cierto punto del resultado de estos estudios.

Otra fuente de aguas subterráneas en el Norte de Chile, y en diversas zonas del resto del país, son los depósitos de terciario superior y cuaternario en las cuencas grandes que contienen estratos de materiales finos y gruesos que son resultado de una sedimentación aluvial en el Norte y glacial en el Sur.

Se descubrió agua subterránea surgente como resultado de un programa exploratorio llevado a cabo en el Salar de Atacama, un gran valle al sureste de Calama (Fig.I). Esta representa una fuente enteramente nueva de agua para esa zona como asímismo representa las posibilidades de un desarrollo adicional, ya que durante algunos cientos de años se utilizó el agua superficial que es muy limitada alrededor del paralelo de San Pedro de Atacama, como único sistema de regadío.

La zona de Chillán en el valle Central (Fig.I) contiene por lo menos 300 metros de depósitos de orígen fluvio-glacial. En la actualidad se usa un sistema de canales para conducir el agua de riego que se usa en la seca temporada de verano; estos canales y algunas norias proporcionan también el agua para uso doméstico.

Como resultado de un programa de perforaciones exploratorias y de investigaciones geológicas, se encontró agua subterránea artesiana que en la actualidad se utiliza como una fuente adicional de riego la cual ha incrementado la productividad de esa zona.

En la zona de San Carlos, 30 kilómetros al norte de Chillán se encontró agua subterránea surgente, entre las cuales existe un pozo que produce un gasto permanente de 65 lts/seg.

Santiago con una población aproximada de 2 millones de habitantes está utilizando tanto el agua superficial como la subterránea. El agua superficial se trae en gran parte desde la Cordillera por medio de tuberías; debido al incremento tanto de la población como de sectores industriales la demanda de agua subterránea ha ido en aumento.

Con anterioridad a 1956 ningún estudio se había hecho con respecto a la fuente de agua subterránea en esta zona, como tampoco se había recolectado informaciones básicas. Con posterioridad a esta fecha el Instituto de Investigaciones Geológicas ha estado obteniendo datos que incluyen la cifra de 3.18 m3/s como consumo de agua subterránea en la zona y una declinación del nivel estático del agua de 1 mt/año en las áreas de mayor extracción.

Será ahora posible proponer un desarrollo y uso más racional del agua subterránea en la zona.

La Corfo está ahora llevando a cabo un programa de perforaciones exploratorias para determinar la profundidad del lecho rocoso del valle central en Santiago, información que no sólo es de valor en lo que a aguas subterráneas se refiere, sino que también proporcionará un mejor conocimiento de la estructura y profundidad del valle central en toda su extensión.

5.- Labor actual y orientación futura.

La necesidad de poder contar los mayores antecedentes posibles de los recursos de aguas subterráneas que hoy se explotan en el territorio ha hecho que Corfo en conjunto con el Instituto de Investigaciones Geológicas haya efectuado una recopilación de todos los pozos construídos en Chile, ya sea por organismos fiscales como por empresas particulares. De este modo se han ubicado en mosaicos de fotos aéreas de nuestro territorio alrededor de 1.400 pozos profundos, que constituyen la mayoría de los trabajos realizados y que permitirán conocer las zonas de mayor explotación de estos recursos.

Junto a esto, Corfo está efectuando estudios de cada hoya hidrográfica del territorio, en los cuales además de conocer las posibilidades que cada zona presenta para un futuro desarrollo de las aguas subterráneas, se están analizando las necesidades que cada región presenta tanto en el aspecto agrícola como en el industrial, minero y de abastecimiento de poblaciones. Así, se podrá planificar los futuros trabajos que se desarrollen en esta especialidad, otorgándose las necesarias prioridades a los diferentes proyectos.

Uno de los factores que más importancia ha dado Corfo al desarrollar esta especialidad, es la preparación de personal técnico competente para el uso de las diferentes maquinarias. Con este fin, todos los años se realizan cursos especiales de formación de operarios que ha permitido ir mejorando la eficiencia en los trabajos de esta nueva especialización.

Como ya se ha manifestado, Corfo ha dedicado gran parte de su trabajo a la exploración en áreas desconocidas bajo el aspecto de aguas subterráneas. En algunas de estas áreas los resultados favorables han creado un interés en los habitantes en la demanda de nuevos pozos que son construídos por compañías privadas de perforación, creadas en los últimos años.

De esta manera la Corporación de Fomento está contribuyendo al estudio y aprovechamiento de estos recursos naturales, indispensables para el desarrollo de gran parte de la economía de este país.

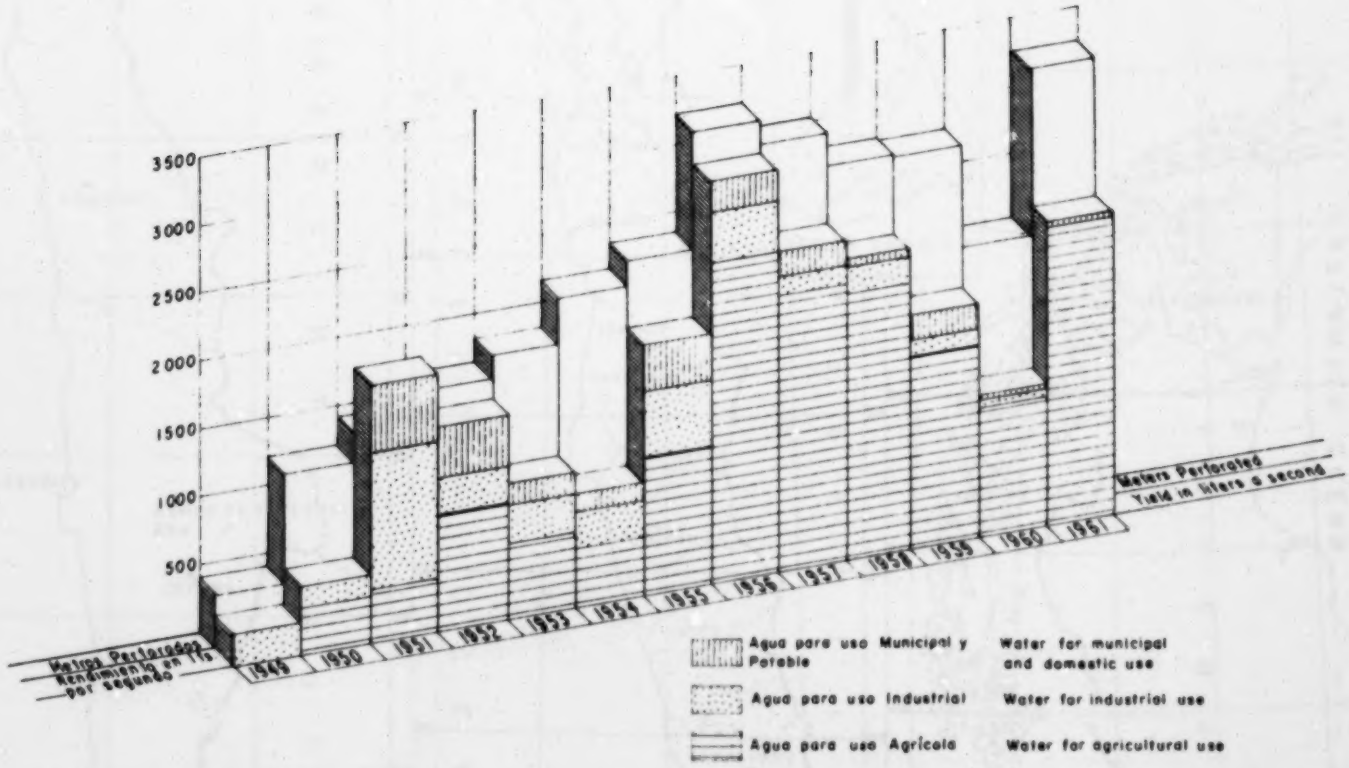

Fig. II.— Metros perforados y litros por segundo de agua subterránea obtenida para uso Agrícola, Industrial y Municipal en los años comprendidos en el período 1949–1961

Meters perforated and yield in liters a second of ground water for agricultural, industrial and municipal use obtained during the period 1949–1961

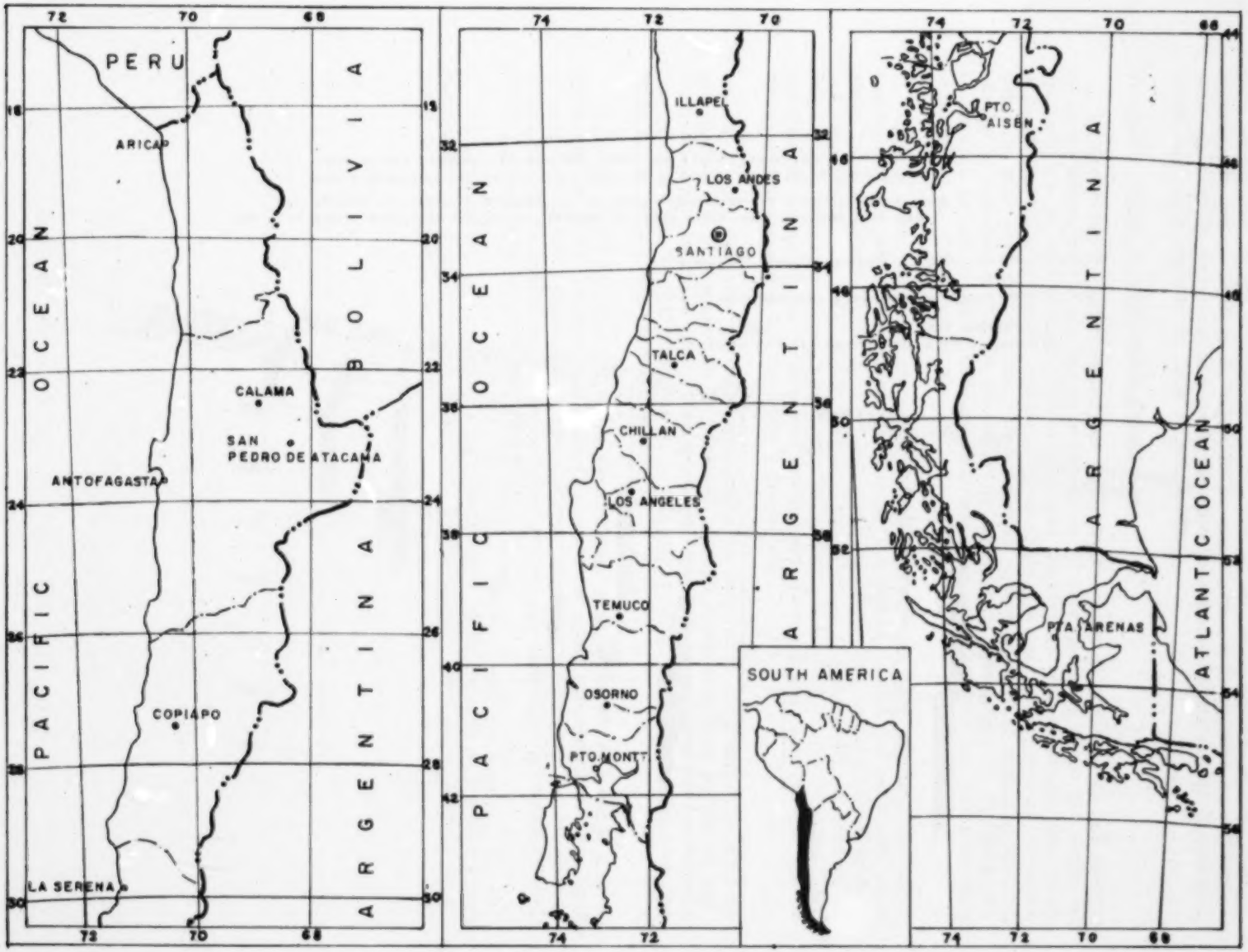

Figure I.— Index map of Chile
Mapa indice de Chile

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UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A

Hungary

LONG-TERM PLANNING OF ENERGY ECONOMY FOR LESS DEVELOPED AREAS

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A

LONG-TERM PLANNING OF ENERGY ECONOMY FOR LESS DEVELOPED AREAS

by

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Statistical investigation of national income and of energy consumption

/1/ Experts active in the field of energy supply have long since endeavoured to find a relationship between the energy consumption and the per capita national income, the latter being the most important measure of the welfare of a country. Knowledge of this relationship will permit to establish the efforts worth making in the individual countries to secure the energy supply on the one hand, and to determine the quantities of energy required to attain a planned increase in the national income, on the other. Searching for the relationships between the various index numbers characterizing the national economy and the consumption of energy is a significant aid for the long-range planning of energy supply. However, considerable care must be taken when making use of such deduced relationships since - as to be proved later on - the special features of the individual areas may considerably modify the conclusions drawn on the whole.

/2/ The relationship between per capita national income and per capita energy consumption was established by Mason[1] among others. In accordance with the data compiled by this author, Fig.I. shows the relationship mentioned above in reference to the less developed countries. The correlation of the two variables is distinctly recognizable in the

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1 Mason, E.S., Energy Requirements and Economic Growth. International Conference for the Peaceful Uses of Atomic Energy, held at Geneva, August 1955. Doc.P/802/1955/.

figure in spite of the considerable scattering next to the approximating straight line.

/3/ The investigation of the correlation between energy consumption and national income is cumbersome if effected by the method mentioned above, This is partly due to the uncertainty of the available information. When submitting data covering energy requirements, the method of numerically converting energy of higher value /e.g. electrical power/ into other forms of energy is subject to discussions and the scope of national income is not unequivocally established /e.g. whether it covers household work/. Conversion to a common rate of exchange constitutes another source of uncertainty.

/4/ Index numbers supplying information on the increase of energy requirements rather than on their absolute value are more serviceable for the establishment of long-range energy requirements. Within each country, there exists a close connexion between the annual rate of growth of per capita national income and the variations in per capita energy consumption. This is demonstrated e.g. in Fig.II. where, according to Ghaussy[2], the variations in the index numbers of the two specific ratios mentioned above are shown for France, from 1920 to 1956; the closeness of the correlation is clearly presented by the similarity in the shape of both graphs. Energy consumption traces even the minor fluctuations of national income.

/5/ The idea may be raised to make inferences concerning the prospective development of less developed countries from the earlier development of more developed countries. This, however, is mostly impracticable since the less developed countries do not, to-day, have to solve the problems of their energy supply by means of the old-type equipments, obsolete from the present engineering point of view. The conditions of development therefore, differ, considerably. Furthermore, the possibilities of comparison are greatly disturbed by the relapses /due to wars, economic crises, natural catastrophes/ that have occurred in the development of the industrially developed countries.

/6/ For illustrating the conditions of development, a comparison of the simultaneously occuring data of various countries may be chosen. Utilizing the data contained in the 1961 Statistical Yearbook of UNO, we have carried out calculations to establish relationships between the increases in energy requirements and those in national income by comparing various countries rather than within a single country.

/7/ In Table 1, four indexes are listed for each country - based upon data supplied by UNO[3] - for which correlations are sought for by the rules of mathematical statistics:

X_1 - Average annual increase of per capita income from 1957 to 1960, %;

X_2 - Proportion of the 1958 national income derived from agriculture, forestry and fishery %;

X_3 - Per capita energy consumption in 1960, kg of coal equivalent;

Y - Average annual increase of per capita energy consumption from 1957 to 1960, %.

/8/ First, let the direct correlation between the annual increase of per capita national income /X_1/ and the annual increase

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2 Ghaussy, A.G., Die Rolle des Energiesektors in der Entwicklungspolitik. Westdeutscher Verlag, Köln und Opladen /1960/, p.40.

3 Statistical Yearbook 1961. United Nations, New York /1961/.

of per capita energy consumption /Y/ be investigated. The percentual variations are shown in Fig.III. It can be seen that hardly any relationship exists between the two indexes: the coefficient of correlation - according to our calculations - is 0.24. The slope of the regression line is rather small. The slackness of correlation is due to the fact that, besides the influence of variations in the national income, other factors also effect considerably the increase of energy consumption.

/9/ It stands to reason that the rate of growth of energy consumption is affected by the distribution of the increase in national income among the contributing branches of national economy, that is by the fact, whether the increase originates in industry with a high energy consumption or in agriculture with a low energy consumption. Let a further variable be included in the computations, that which indicates the percentual proportion of agriculture, forestry and fishery in the absolute value of the national income /Table 1,X_2/. Instead, the use of a characteristic indicating the proportion of the branches mentioned above in the increase of national income /and not in its absolute value/ would, of course, have been more practicable, the relevant data, however, are rather incomplete.

/10/ The calculations have shown that the introduction of this new variable has tightened the correlation considerably, the correlation coefficient increasing from 0.24 to 0.51. The correlation however, cannot yet be regarded as close. The significant increase in correlation also indicates that energy consumption depends, to a much higher extent, upon this new variable, as shown clearly in Fig.IV. The regression line is much steeper in this figure.

/11/ An attempt has been made to introduce yet another variable, the absolute value of per capita energy consumption /Table 1,X_3/. The effect of this new variable is not significant, its introduction increases the correlation coefficient but slightly, from 0.51 to 0.52.

/12/ In Figs.III. and IV. the regression lines are shown as functions of two variables /X_1, X_2/. Accordingly, the per capita increase in energy consumption may approximately be obtained, by means of the following equation:

$$Y = 0.227\ X_1 - 0.194\ X_2 - 3.86.$$

/13/ As observable in Figs.III. and IV. there are considerable deviations in respect to the regression lines due to causes not taken into consideration. The correlation of the indexes taken into account is, therefore, weak even if demonstrably present. Certain inferences, however may still be made from the investigations and approximate figures can be obtained for long-range energy production. It can be primarily established in this manner that in less developed countries, largely, a 3.5% increase of energy requirements corresponds to a 2.1% increase in the national income. However, in consideration of the fact that energy requirements undergo an increase on account of technical developments /approx. 2.5% annually/ even when the per capita national income does not grow, every percent change in the national income will imply on the average only a 0.4% change in energy requirements /see regression line in Fig.III/. If, besides the planned increase in national income, the percentage of the national income originating from agriculture, forestry and fishery is also given, the prospective increase in energy may be calculated by this formula. For instance, should the national income grow by 3% in a country where 40% of the national income is yielded by agriculture, the prospective increase in energy consumption will amount to 4.6%.

/14/ These computation methods are, in general, too inaccurate to permit the direct utilization of their results in the long-range planning of energy requirements. Energy requirement estimations of such character may be used as a basis, only if detailed data on the economic development of the area subject to investigation are not available. The methods mentioned above are suitable for the preparation of planning, for a crude characterization of perspective conditions, rather than for planning itself.

Methods for determining long-range energy requirements

/15/ The factors determining the long-range plans of energy supply are the long-range objects of economic development, for whose realization power and fuel economy are indispensable means. It is obvious, however, that the actual possibilities of energy supply must be taken into consideration when setting long-range aims /national income, industrialization, employment, living standard, etc./.

/16/ This implies, for the purpose of practical planning, that the qualitative and quantitative distribution of energy sources to be made available to national economy must be determined on the basis of the theoretical energy requirements - from the quantitative and qualitative distribution of the necessary forms of energies - needed for realizing the aims of long-range economic development, with due regard to the technical possibilities and the costs of energy supply.

/17/ The necessary forms of energy are qualitatively determined by the objects of utilization specified in conformity with the individual components of the national income. The most important forms of energy, from the viewpoint of quantity, are heat, mechanical energy and chemical energy. Several energy sources are available to satisfy the demand for the various forms of energy.

/18/ The qualitative dissimilarities of the energy requirements, as described above, make it necessary to investigate energy requirements both summarily and separately, according to the forms of energy. In order to consider summarily the various energy forms - convertible into each other - and energy sources, there is need for a common unit of measurement, such as the calorie or the kWh. The theoretical and practical problems of the conversion of units of measurement are dealt with in detail by LAADING[4].

/19/ The methods employed to determine energy requirements may be classified into two main groups. To the first group belong the so-called global methods of estimation, generally used for the summarized estimation of the total energy requirements and - practicably - for estimating the requirements in respect to a certain form of energy source /primarily to electric power/. The methods described under /2/ and /13/ also belong under this heading. According to experiences in Hungary, it is desirable to deal separately at least with the requirements for heat and for mechanical energy /electric power/ when making global estimations of the total energy requirements. A basis of global estimation may be obtained by extrapolating to the future a known trend of energy consumption of a past period, or the

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4 LAADING,K.F.,Methods for Establishing Overall Energy Balance Sheets. World Power Conference, I A1/8.Madrid /1960./

future development of a series of data referring to economic development /national income, volume of industrial production, etc./ as a function of which the prospective energy requirements can be calculated on the basis of similar relations in the past. Knowledge of the statistical data referring to the bygone period is an indispensable precondition in either case.

/20/ With the so-called synthetic method of calculation, the prospective requirements are determined separately for each of the branches of national economy, making allowance for the prescribed or prospective long-range tasks in the individual branches.

In industry, the growth of production must be considered, separately investigating the development of the various branches of industry, that of energy-intensive products /metallurgical and chemical products, building materials, products of the light and food industries,etc./ and the prospective development of specific energy consumption per unit product. Specific energy consumption primarily depends upon the technology of production, upon the engineering level of production, upon the chosen energy source.[5]

/21/ In the field of transport, the prospective energy requirements can be computed on the basis of the envisaged tasks of transport. Railway, highway, water and air transports must be separately investigated and the energy requirements both of passenger and goods transports must be examined separately for each of the above. The energy requirements of agriculture constitute a relatively small proportion of the national energy requirements; depending primarily upon the degree of mechanization of agriculture, they present themselves mainly in motor fuels and electric power. The heat requirements of agriculture are relatively low /drying,etc./. Household and communal energy requirements can be calculated by analyzing the energy consumption per inhabitant or - for higher accuracy - per household /home/. A considerable proportion of this energy may consist of energy used for heating, depending upon the geographical situation and weather conditions of the given area.

/22/ A precondition for applying either of the methods outlined above is the knowledge of statistical data characteristic of the energy consumption of the given area. The reliability of planning greatly depends upon the accuracy and detailedness of the statistical data.

/23/ Which to choose of the global or synthetic methods depends upon the detailedness of the plans for the economic development of the given area. With detailed plans available, application of the synthetic method, based upon fundamental data in greater detail, will be the more practicable.

/24/ It is advisable to use the global method of estimation even when fundamental data are available in necessary detail for calculation by the synthetic method. This offers the possibility - according to experiences gained in Hungary - to check the results obtained by the sythetic method.

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5 A serviceable aid to planning are the data collections containing data on specific energy consumption, e.g.:
Scholl,W.,Mackethun,W.,Masukowitz,N., Anhaltszahlen über den Elektrizitäts-, Kraft- und Wärmebedarf der Industrie. VDEW, Frankfurt a.M./1951/.
Ringbuch der Energiewirtschaft, Frankfurt a.M./Continually since 1952, on loose leaves/.
Anhaltszahlen für die Wärmewirtschaft in Eisenhüttenwerken. 5.neubearb.Aufl. Verlag Stahleisen, Düsseldorf /1957/.
Wärmeverbrauch in Industrie und Haushalt. VDI-Verlag,Düsseldorf /1959/.

/25/ A sound basis for calculating long-range energy requirements may be gained by the analysis of the data of a country or area that had previously undergone economic development of a similar character.It is advisable,'in this respect, to compare primarily such areas whose natural resources and climatic conditions resemble, on the condition that the difficulties outlined under /5/ do not prevail.

/26/ On the base of the energy requirements determined by the global or synthetic method, the energy supply required for producing the national income can be elaborated in a number of variants since the energy sources suitable for supplying the individual forms of energy /heat,mechanical energy, chemical energy/ can be substituted for each other within certain technical limits. The task lies in determing the variant ensuring an optimal energy supply from among the numerous possible combinations of energy sources.

/27/ When establishing the provisions to be made for the development of national economy /national income, volume of industrial production, etc./, taken as a basis for determining the energy requirements, the optimal variant of energy supply - determined as described above - and the effect of this variant upon foreign trade, industrial production, transport, etc. cannot yet be known. Consequently, after the conclusion of the calculations, it must be checked whether the optimal variant of energy supply can be brought in harmony with the originally set aims of economic development; otherwise, provisions must be made to co-ordinate the individual tasks of development.

/28/ One of the most important requirements in the development of less developed countries is the fast and vigorous increasing of labour productivity. The fundamental means to achieve this aim is to mechanize production, i.e. the substitution of human /and animal/ effort by mechanical work, and then extending the application of the latter. In present technical practice, the utilization of mechanical energy commonly implies the use of electric power, that is electrification, if transport is disregarded.

/29/ The mechanical energy demanded by transport will presumably be supplied by oil products /petrol, gas oil, diesel oil/, but electric railway traction may also be taken into account.

/30/ Worthy of consideration under the special circumstances of certain areas are the utilization of wind power and of digester gas, the latter obtained by the gasification of agricultural wastes.[6]

/31/ A fundamental question in electrification is the choice of the primary energy sources /fuels, water power and, perspectively, nuclear fuels/. A special task of electrical-power economy consists of satisfying load requirements, especially peak loads.The determination of long-range energy requirements must, therefore, be completed by determining the peak load. An adequate basis for solving this question is offered by planning the energy requirements.

/32/ For covering heat energy requirements, fuels are to be considered primarily, however, the perspective possibilities of directly

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6 Gádor,E., Local Sources of Energy, Micro-hydroelectric Stations, with particular Emphasis on the Electrification of Agriculture. Section A.4.3.3 of this Conference.

utilizing solar radiation - especially for countries in the tropics and subtropics - must also kept in mind. Characteristic of numerous less developed countries is the large-scale utilization of vegetal and animal fuels; efforts must be made to substitute mineral fuels for fuel wood and for valuable manure, destined to play an important role in the development of agriculture.

/33/ Fundamentally, there are two circumstances that determine, from the economic point of wiew, the practicable energy sources and their quantitative ratios for producing determined forms of energy in a given case: the prices of the energy sources and the investment and operational costs entailed by their use on the one hand, and the utility of the energy sources related to their technical applicability, on the other.

/34/ As to the costs of energy supply, the costs of the energy sources are not the only point. Not only energy sources are needed to supply the consumers with energy, but also energy conversion and distribution equipment on the one hand, and consuming equipment, directly utilizing energy in the final stage, on the other. Figuring among the costs of energy supply are the total costs of energy conversion, distribution and utilization as well.

/35/ Energy sources suitable for similar consumer purposes /e.g. for firing in boilers/ cannot, however, be utilized with identical effectiveness; this difference in effectiveness is independent of the ratio of the purchase costs. In order to determine the utility - differing for each area of utilization - of energy sources, the technical characteristics, operating and depreciation costs of the energy consuming equipments must be taken into account.[7]

Economic considerations on the establishment of energy-producing, converting, distributing and consuming equipment

/36/ Energy consumption is a close function of the economic structure of any country. In the energy-consuming branches of industry, energy figures as a basic material; the purpose of the energy-producing, converting and distributing branches of industry, however, is the most economical satisfaction of energy requirements.

/37/ Energy production, conversion and distribution demand high capital investments. Table 2 lists the relative values of specific requirements for fixed capital in the individual branches of energetics, including the dependent requirements for fixed capital in the allied branches, founded upon data obtained in Hungary. Thus, for instance, the capital investments made in mining, conforming to the coal requirements, figure among the data of electric-power generation.

/38/ Except petroleum refining, the branches playing a role in energy supply require higher capital investments than the average industrial production. This primarily refers to electric-power generation and gas production.

/39/ The share of the energy-producing branches of industry in the total of capital investments of a country depends upon the structure

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7 Sóváry,E., Bewertung der Energieträger.II.Konferenz für industrielle Energiewirtschaft, Budapest, den 16-21.Oktober 1961.Energiagazdálkodási Tudományos Egyesület, Budapest /1961/.

of industry. In 1954[8], about 18 % of the total investments of the European countries were investments in the energy sector and this share tends to increase. Besides the greater rate of development in the branches of industry with high energy consumption, this growth is due to the fact that energy production, and mainly coal production, demands ever increasing investments of capital owing to the decrease of coal supplies.

/40/ In view of the high requirements for capital investments in energy supply, the co-ordination of this development with the development and energy requirements of the other branches of industry and of national economy is of high importance. Disproportionate development may give rise to grave difficulties in the economic life of a country. Backwardness in the supply of energy may entail the introduction of compulsory restrictions in certain sections of consumers, primarily in industry, causing heavy losses on account of the lack of exploitation of consumer equipment. Overdevelopment of the energy supply, on the other hand, results in a superflous immobilization of capital. The excessive lenght of the periods of capital investment in important energetic developments /about 3 years for power stations, 5-8 years for mines/ constitutes another drawback owing to which long-term plans cannot be modified at short notice. The acceleration of capital investments is a task of special difficulty nor is their postponement an easy one since the suspending of already commenced investments may cause heavy economic damages by losing the interest of the capital invested.

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8 Europe's Growing Needs of Energy. OEEC, Paris /1956/.

Table 1.

Statistical data characteristic of national income and of energy consumption

Country	Avg. annual increase of per capita national income 1957-1960 X_1 %	Proportion of agriculture, forestry and fishery in national income 1958 X_2 %	Per capita energy consumption 1960 X_3 kg	Avg. annual increase of per capita energy consumption 1957-1960 Y %
Brazil	4.2	26	372	7.1
Burma	2.4	41	55	10.3
Chile	1.0	14	883	1.7
Cyprus	-5.2	23	829	-4.5
Equador	1.2	36	177	5.7
Malaya	3.9	46	241	0.6
Korea	1.8	41	254	13.7
Pakistan	0.6	54	505	8.8
Paraguay	3.4	45	355	6.2
Philippines	-1.5	33	138	2.3
Rhodesia and Nyasaland	3.0	20	522	-2.6
Thailand	-1.3	38	63	5.9
Jamaica	5.0[a]	31	-528	6.5[a]
Malta	3.8[a]	8	449	-3.2[a]
Cambodja	-0.4[a]	47	31	7.2[a]
Columbia	10.4[a]	37	480	1.7[a]
Congo	-2.7[a]	26	81	-10.8[a]
India	3.6[a]	50	138	4.2[a]
Indonesia	6.8[a]	60	135	4.3[a]
Average	2.11	35.6	310.3	3.54

[a] 1957-1959

Table 2.

Total indirect and direct requirements for fixed capital in Hungary, belonging to identical production values in the individual branches of energetics. /The average requirements for fixed capital in industrial production = 1,0/

Electric-power generation	3.0
Town gas production	2.3
Petroleum and natural gas production	1.8
Peat mining	1.5
Coal mining	1.4
Briquetting	1.2
Petroleum refining	0.6

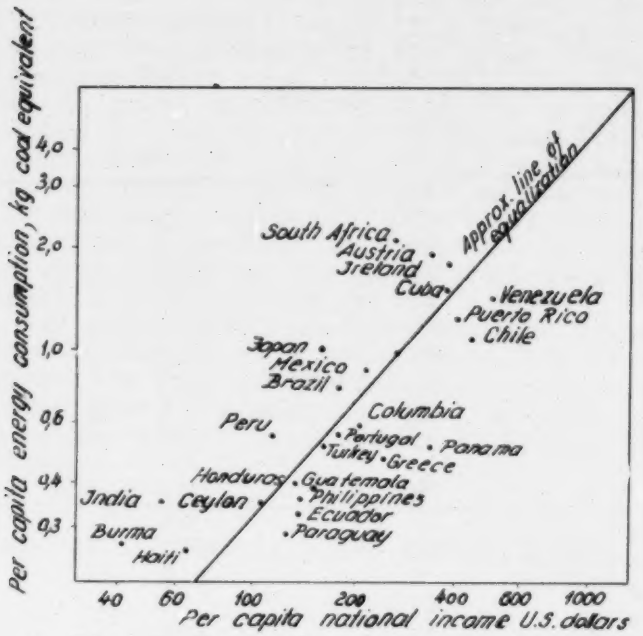

Fig. I National income vs. energy consumption

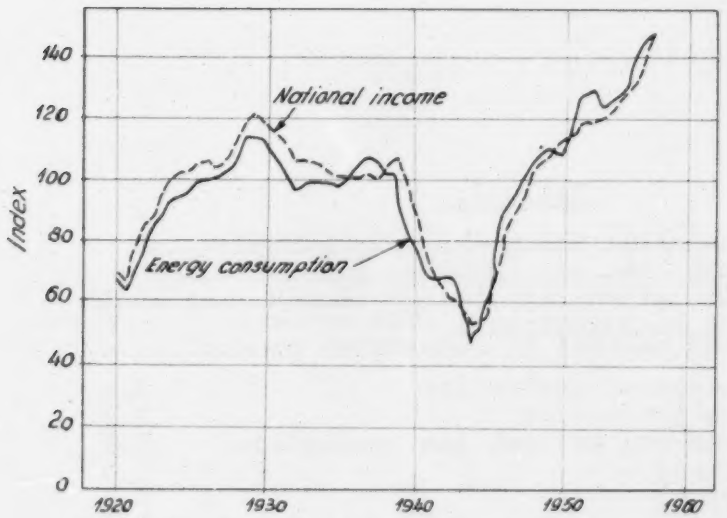

Fig. II Variations in the indexes on national income and energy consumption in France

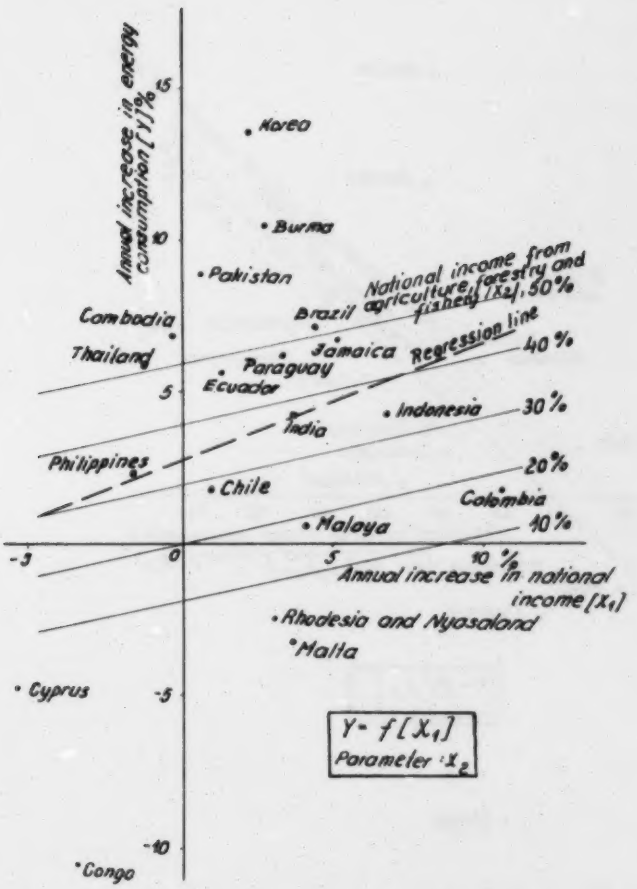

Fig. III Annual increase in energy consumption vs. annual increase in national income

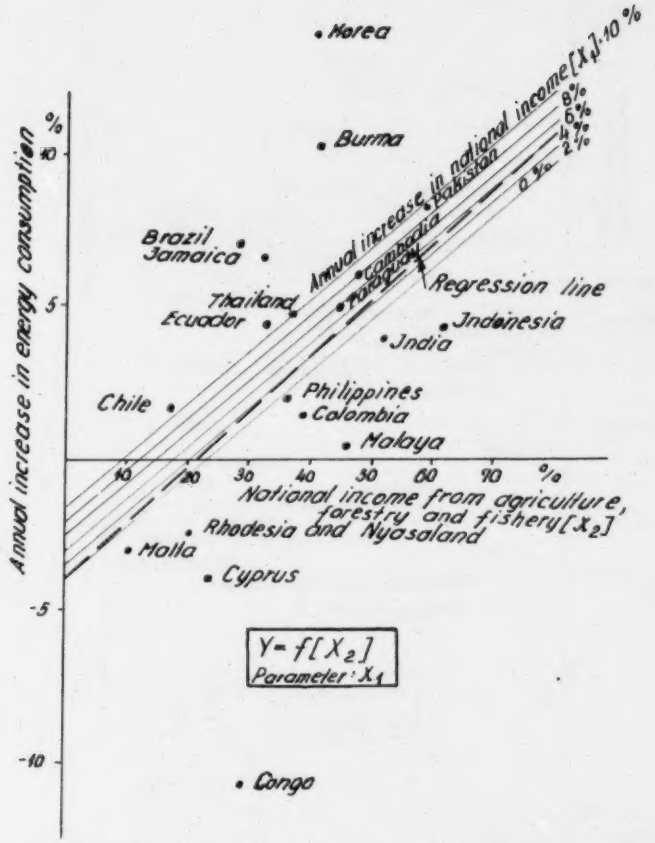

Fig.IV Annual increase in energy consumption vs. relative share of agriculture in the national income

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UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A. 2

Japan

ALLOCATION OF STORAGE CAPACITY OF A RESERVOIR FOR MULTI-PURPOSE USE

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Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages.

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ALLOCATION OF STORAGE CAPACITY OF A RESERVOIR FOR MULTI-PURPOSE USE

by

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I. HISTORY OF JAPAN'S MULTI-PURPOSE DAM PROJECTS

1. The history of multi-purpose dam projects in Japan dates back about forty years. In 1923, Dr. Mononobe, the then Director of the Public Works Laboratory of the Ministry of Home Affairs, submitted to the Government an opinion that rivers should be developed on a comprehensive basis. The main points contained therein are as follows:

(a) Since the vast river channel resulting from river improvement can demonstrate its full capacity for only a very short period, it is felt that controlling the river discharge by storage of water would be more advantageous for flood control.

(b) One of the climatic characteristics of Japan is that in winter there is a dearth of water, which decreases the output of water-power generation. Since there are no floods during this season, the capacity allocated for flood control may be utilized for power generation.

(c) In view of the fact that, generally speaking, there are not many suitable reservoir sites in our country, it is desirable to make their use multi-purpose.

(d) As a measure to prevent reservoirs from becoming filled up with sand, erosion control works must be carried out on more extensive scales.

(e) If a plan is developed to suit only the convenience of power generation, it may cause harm to other uses of the river, so a plan should be worked out by persons who are well acquainted with every aspect of the river.

2. In short, it was stated that since Japan's feasible reservoir sites were limited in number, being subject to various conditions such as the topography, geology, compensation, etc., she must develop her river systems in a manner most advantageous for flood control and water utilization after making investigations relative to the anticipated flood-control and water-utilization effects of the development projects.

3. Based on this opinion, requests were submitted starting in 1926 for budgetary appropriations needed to carry out investigations on the control of river water. However, it was only in 1937 that such appropriation was approved for the first time. Its breakdown was: 250,000 yen to the Ministry of Communications and 100,000 yen to the Ministry of Agriculture and Forestry.

4. The Ministry of Home Affairs undertook investigations for 67 rivers during the five year period from 1937 to 1941. With regard to these rivers, works were started successively upon completion of the respective investigations. The works of river control projects were started for 25 rivers prior to the Pacific War. Of these, only those for 11 rivers were completed. After the war, the projects suspended during the war were resumed, and also new investigations were undertaken. Of the investigations conducted from 1947 by the Economic Stabilization Board, with the cooperation of various Ministries, concerning development of 24 rivers, some were carried out by the Ministry of Construction. In addition, the Ministry of Construction was made responsible for conducting investigations

from an independent standpoint on rivers that had to be developed, to meet the requirements of the various purposes such as flood control, irrigation, power generation, etc. and for executing the projects.

II. COMPARISON OF CHARACTERISTICS BETWEEN PREWAR AND POSTWAR MULTI-PURPOSE DAM PROJECTS

5. The basic line of thinking in the planning of multi-purpose dams in the prewar days was to store in reservoirs the copious water of the season with much rainfall in summer and discharge it in the period of water shortage in winter to use it for power generation, irrigation and other purposes of water use.

6. The climatic conditions of Japan are different from those of the continent. There is no definite dry season or rainy season definable as such. What we call the rainy season is one in which there is a relatively large amount of rain and the dry season is one during which we have relatively little rain. Moreover, since the water courses of rivers are short, the longest being 200 km or so, the rain runs down to the sea in the course of a few days without feeding the underground stream to any notable extent, and changes of the discharge are very conspicuous. The ratios of the maximum discharges to the minimum discharges are shown in Table 1, from which can be seen the sharpness of changes in the discharge of Japanese rivers. Furthermore, droughts often extend over long periods

TABLE 1.

Country	Name of river	Ratio of max. to min. discharge
Japan	Tone	236
Japan	Chikugo	473
U.S.A.	Colorado	100
France	Seine	23
	Rhein	14
	Mekong	35
India	Ganga	35

TABLE 2. Unit: Million cubic meters

Country	Name of dam	Dam volume (A)	Storage capacity (B)	B/A
Japan	Sakuma	1.0	327	327
do	Narugo	0.2	54	270
U.S.A.	Hoover	3.4	38,400	11,400
India	Bhakra	3.9	4,300	1,100
Switzerland	Mauvoisin	2.0	160	80
Italy	Santa Guistina	0.1	172	1,720

of time. In checking the highest values of the continuous number of days without precipitation in the past years, we find that in not a few instances the value exceeds 50 days. Such being the case, it is extremely difficult to make the discharge of Japanese rivers constant.

7. Besides the meteorological conditions, there may be mentioned another important factor which makes it difficult to obtain constant river discharge —— viz. the fact that the capacity of reservoirs is small. As our country has steep topography, the storage capacity of a dam is very small even if it is constructed to be a high dam: such a dam is naturally very uneconomical, the storage capacity per cubic meter of concrete being only 200 - 500 cu m (Table 2). The availability of rivers' discharge can be increased by construction of dams. However, owing to the said meteorological and topographical disadvantages, it is necessary to construct a considerably large number of dams in order to really improve the availability of Japanese rivers. For reference, the relation between the storage capacity and the use percentage of the Tone and the Yodo, two typical rivers of this country, is given in the following table.

TABLE 3. Unit: 1,000,000,000 cubic meters

Condition	Natural	5 dams	Before development of Lake Biwa	After development
Total run-off	13		10	
Storage capacity	0	0.3	0.9	1.7
Total use tonnage	3.2	4.8	4.3	6.6
Storage cap./ Total runoff	0	2%	9%	17%
Use rate	29%	37%	43%	66%

8. Owing to such inefficiency of Japanese reservoirs, none of the multi-purpose dams constructed in the prewar years produce satisfactory results. This is especially the case as to their function of flood control. The author selected Okiura dam and Sagami dam as typical examples of multi-purpose dams projected in the prewar days and checked their flood control plans and the actual results thereof, the results being given in Table 4. The storage capacities are too small to achieve the expected results when floods occur. Considering that the

TABLE 4. Flood control

	Name of dam	
	Okiura	Sagami
Catchment area km^2	200.8	1016
Scheme included	F,A,P	F,P,A,W
Effective storage m^3	2,281,000	42,200,000
(Equivalent rainfall) mm	(11)	(42)
Design flood discharge m^3/sec	344	2,650
Regulated by m^3/sec	254	300
Annual power generation KWH	4,470,000	135,234,000

Actual Operation of flood control

Date	Sep.18/'58	Aug.3/'60	Aug.14/'59	Sep.26/59
Total rainfall mm	173,5	129	356	295
Flood discharge m^3/sec	281	315	2,701	2,078
Regulated by m^3/sec	79	62	254	352
Storage actually used for flood control m^3	620,000	610,000	2,030,000	10,160,000
(Equivalent rainfall) mm	(3)	(3)	(2)	(7)
Actual power generation KWH (year)	8,570,000 1959	8,823,000 1960	148,375,000 1959	112,092,000 1960

F: Flood control A: Irrigation
P: Power generation W: Water supply

vacancy capacity available at the time of a flood is only a few millimeters in terms of rainfall, we should say that the actual operation of reservoirs is conducted with great dexterity.

9. As regards power generation, the results obtained are near the planned figures, as is shown in the same table. This has been brought about by the intention of the administrators of the power generation projects to heighten the storage level in order to bring advantage to their power generation projects shown in terms of income. From the standpoint of flood control, the planned effect cannot be hoped

for unless the dam is vacant for the capacity necessary for flood control whenever a flood occurs. On the other hand, from the standpoint of the enterprisers of water utilization such as power generation and domestic water, it is desirable that the reservoir be one that can readily meet any demand and be operated most economically. If possible, it is desired that the storage level be always kept near the full water stage.

10. When a dam is used for two or more purposes, this conflict between the purposes is inevitable so long as their aspects of use are different. In planning a dam project, it is prerequisite to establish an operation method of the reservoir which satisfies all the enterprisers concerned. In the postwar multi-purpose dam projects, this way of thinking was developed into the idea of capacity allocation of the reservoir.

11. The multi-purpose dams built in the postwar years under integrated river development projects can be distinguished from the prewar multi-purpose dams by the establishment of the ideas of cost allocation and capacity distribution. With regard to the cost allocation, the alternative justifiable expenditure method which is now adopted in Japan is essentially connected with the problem of capacity distribution. In this sense, it may be said that the idea of capacity distribution is the most significant feature of the multi-purpose dams in postwar Japan.

III. BASIC IDEA OF CAPACITY ALLOCATION

12. Capacity allocation is the conceptually established use division of the water storage levels intended for the most rational use of water. As was stated in the preceding paragraph, the biggest defect of the river water control projects in the prewar years was in the fact that it was not clear what storages were available for the respective purposes. In view of such experiences, capacity allocation came to be adopted in the projects in the postwar days.

13. The kinds of water storages according to the present Japanese division are: the sand sedimentation capacity V_s, dead water capacity V_d, flood control capacity V_f, power generation capacity V_p, irrigation capacity V_a, industrial water capacity V , and domestic water capacity V_w, The respective storage capacity are determined as follows:

(a) Sand Sedimentation Capacity

As a rule, the amount of sand and detritus produced in the catchment area above the dam in the course of 100 years is taken in determining the capacity. In Japan the durability of dams is fixed at 80 years, so the amount to be produced in 80 years may be adopted. However, considering some factors including the difference between the design sedimentation and the actual sedimentation, we adopt the 100-year sedimentation.

(b) Dead Water Capacity

In a dam exclusively for power generation, the low water level for use of the storage water cannot be made lower than a certain limit for the reason of power generation efficiency, and so the water below the level is usually kept without being used in the form of dead water. In the case of multi-purpose dams, provision is sometimes made for dead water capacity.

(c) Flood Control Capacity

We determine the storage capacity necessary for flood control on the basis of the quantity to be cut out of the peak discharge necessitated for flood control of the lower reaches according to the imaginary design flood type at the dam site, establishing the rules of flood control taking into consideration the actual operation and flood discharging facilities. In fixing the actual flood control capacity, it is customary in this country to add a 10 - 20% allowance to the calculated flood control capacity.

(d) Power Generation Capacity

In Japan the only conflict of the storage capacity for power generation with another storage capacity occurs in summer when it conflicts

with the storage capacity for flood control. As there is no essential conflict between the capacity for power generation any other capacity, all the effective storage capacity fixed by the combination of the capacities other than the flood control capacity is utilized for power generation, and the power generation project is worked out on the basis of the supply and demand of electicity within such limit.

(e) Irrigation Capacity

The necessary storage capacity is determined on the basis of the quantities of water necessitated for irrigation of the lower reaches in the respective seasons of the year according to the established rules of discharge.

(f) Industrial Water Capacity

(g) Domestic Water Capacity

Both are determined on the basis of the imaginary need of water in the cities in the lower reaches along the river.

14. When the storage capacities for the respective purposes have been determined in these ways, the scale of the multi-purpose dam is determined on the basis of the combination of the capacities. However, if the calculation were to be the simple addition of the respective capacities, construction of the multi-purpose dam would bring no great advantage: it would be meaningless. What brings economy is to communize the storage capacity on the condition that the respective purposes can secure the minimum necessary water. Therefore, let us consider what combination of the said capacities will make the dam project most economical.

IV. COMBINATION OF STORAGE CAPACITIES FOR VARIOUS PURPOSES

15. Of the storage capacities enumerated above in (a) through (g), the capacity mentioned in (a) is always determined regardless of the capacities for the other purposes because it is necessary for ensuring the functions of the other purposes. The capacity referred to in (b) is the capacity for the water level which it is necessary to establish above the surface of the sediment in connection with the absorption of air caused by whirlpools at the time of power generation. Therefore, it will suffice for us to tackle the problem: how to minimize the total capacity by proper combination of the storage capacities given in (c) and the following items in order to achieve the most efficient use of water.

16. It is uneconomical always to keep the flood control capacity empty, and there are three conceivable remedies:—— the first is the method of ensuring the vacancy capacity by preliminarily discharging the reserved water when there is a fear of flooding; the second is the method of changing the vacancy capacity according to the respective periods during the flood season on the basis of the size and severity of the anticipated floods; the third and last is the method of controlling floods by temporarily raising the water level within the limit of not-overtopping-the-dam at the time of flooding only.

17. In Japan at present, either the first or the second method is employed when there are hydrological data properly arranged and fully analyzed. In case it is easy to purchase the fields for the site of the reservoir, the third method is also employed fairly often. The Japanese methods of securing the water level for flood control for the multi-purpose dams operated by the Ministry of Construction as of 1956 and 1961 are given in the following table, in which you will find advancement in the way of thinking.

TABLE 5.

	1956	1961	Difference	
Number of dams whose purpose includes flood control	29	31	2	
Definite limit water level only	7	4	- 3	
Definite limit water level and preliminary discharge	1	3	2	-2
Definite limit water level and surcharge	13	8	- 5	
Definite limit water level, preliminary discharge and surcharge	1	5	4	
Change of limit water level only	0	7	7	
Change of limit water level and preliminary discharge	0	1	1	4
Change of limit water level and surcharge	4	0	- 4	
Surcharge only	1	1	0	
Preliminary discharge and surcharge	2	2	0	

As is seen in the table, there are indications that the principle of definite limit water level gradually develops to be the principle of changing the limit water level according to the period so that the storage capacity may be utilized for other purposes as far as possible.

18. The reason is that the results of hydrological investigations show it is not necessary to secure a very big storage capacity in relation to the design flood during the period from the beginning of June to the middle of August and in the last ten days of October, because during these periods there are no great floods, which usually occur during the time from the latter part of August to the beginning of October. On the other hand, in the period from the beginning of June to the mid-August water is consumed in large quantities for irrigation and domestic uses. Therefore, in June and July, it is possible to fully utilize the stored water as irrigation water and domestic water by discharging it from the reservoir according to a system. Even if a flood of a smaller size occurs, the flood discharge can be kept within the limit of the drainage capacity of the channel in the lower reaches without causing practically any hindrance to the purpose of flood control. With regard to the flood control system involving preliminary discharge, the number of such type of dams which had been only 4 in 1956 increased to 115 in 1961, which shows that the preliminary discharge system is being positively adopted. This is brought about by the consolidation of hydrological data and the progress of hydrological researches. It is anticipated that this tendency will be strengthened hereafter.

19. In this way, the capacity of flood control, for which the reservoir should be kept empty, can now be utilized for other purposes of water utilization by storing water. It has also become possible to determine the lower limit of the water stage to be kept for irrigation water according to the period by calculation of the necessary storage capacities for the respective periods through analysis of the water dearths in the past. Thus the capacity of a multi-purpose dam is allocated by proper combination of the necessary limit water stage for flood control and the lower limits of water stages for irrigation and domestic water on the basis of the respective values of estimation. The procedure of actual coordination of storage capacity is shown in Fig. 1 for convenience to comprehend what was stated above.

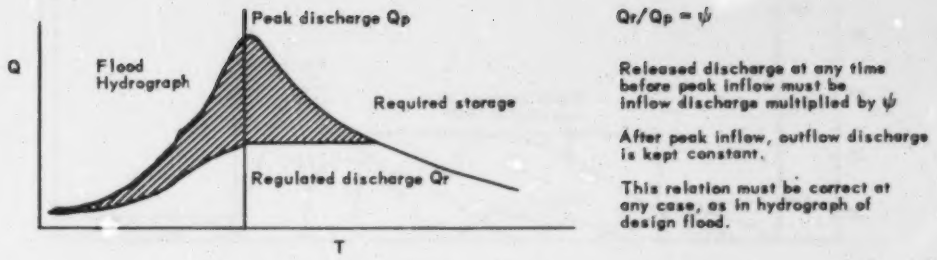
Peak discharge Qp
Q
Flood Hydrograph
Required storage
Regulated discharge Qr
T
Qr/Qp = ψ
Released discharge at any time before peak inflow must be inflow discharge multiplied by ψ
After peak inflow, outflow discharge is kept constant.
This relation must be correct at any case, as in hydrograph of design flood.

Fig. 1 - Decision of required storage for flood control

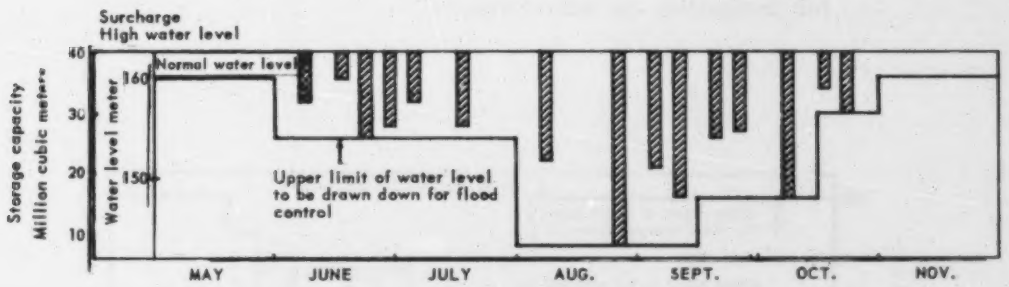

Fig. 2 - Tentative decision of seasonal water-level restriction for flood control

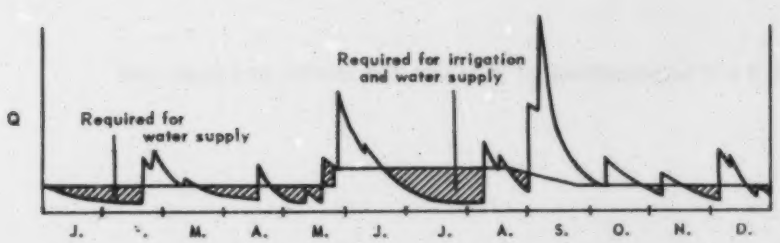

Fig. 3 - Decision of storage capacity to be secured for irrigation and water-supply

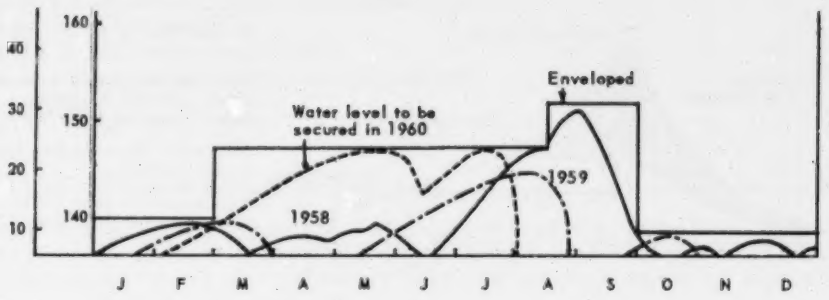

Fig. 4 - Tentative decision of seasonal water level to be secured for irrigation and water supply

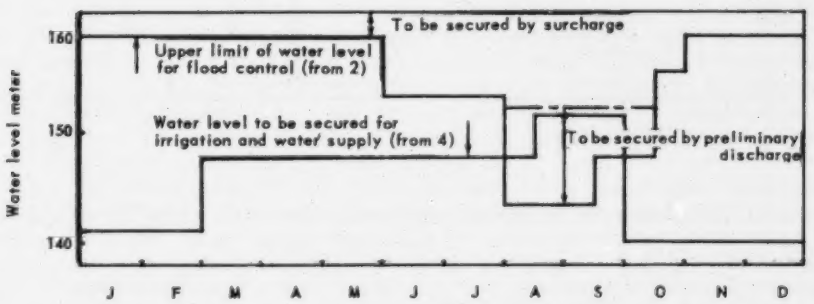
To be secured by surcharge
Upper limit of water level for flood control (from 2)
Water level to be secured for irrigation and water supply (from 4)
To be secured by preliminary discharge
Water level meter
160
150
140
J F M A M J J A S O N D

Fig. 5 - Coordination of storage for multi-purpose use

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UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.1

Brazil

A CRITICAL REVIEW OF BASE-MAP PROGRAMS AS AN AID TO DEVELOPMENT PROJECTS

By John I. DAVIDSON,
Photogrammetry Advisor,
USAID/Brazil

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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No. 380
A.1.

A CRITICAL REVIEW OF BASE-MAP PROGRAMS AS AN AID TO DEVELOPMENT PROJECTS

by
John I. Davidson
Photogrammetry Advisor,
USAID/Brazil

1. Mankind has always required maps, and on too few occasions have maps been available when needed. The need for maps was demonstrated when the first thinking aborigine squatted on his hunkers, and with a finger, traced a sketch in the sand to show friends an easy pass through mountains or the location of a good hunting area. The probabilities are that such maps were fairly accurate considering that the units of measurement were a days walk, or a weeks float on a raft down stream.

2. While one may assume that the specific features which this early cartographer drew were in reasonably correct relative position, it is also a safe guess that there were many blank spaces, or holidays, in his map. In addition to lack of detail or completeness, poor orientation, and variable scales, this first map had three serious deficiencies: 1) it was unique; 2) it was perishable; and 3) it was non-transportable.

3. As time passed and knowledge increased, so did the quality of maps. At the time of the great civilizations around the Mediterrean Sea the knowledge of astronomy, mathematics and writing had developed to a degree that permitted and encouraged great improvements in cartography. Man now had the means of establishing azimuth, or direction, from the stars; had more stable units of distance; and could write and draw on clay tablets or parchment. Furthermore increases in the density of population with attendant government control increased the need for maps, especially to describe property. However the maps of that day still retained one of the original serious disadvantages, that of uniqueness.

4. In fact, although man's ability to compile and draw maps improved greatly, it was necessary to wait hundreds of years for the development of printing presses to overcome the handicap of uniqueness, and be able to prepare maps in quantity from original drawings. Today's multicolor high-speed offset press produces thousands of maps in an hour. So, from the two tools of our first cartographer, memory and a finger, we have come to the point where astronomy, gravity measurements, mathematics, electronics, aviation, photography and photolithography are integrated in the preparation of maps for the benefit of civilization.

5. In the title of this paper, the word critical was used. It was used because of the opinion that makers of policy in development projects underrate the value of maps, are shortsighted in failure to budget for maps, and often neglect to obtain expert advice on what kind of map is needed,

and how to get it. Today many techniques for preparing maps are available. The value of maps in development programs has been demonstrated many times over. In spite of this we encounter opposition to, or at least hesitance, to supply funds for mapping projects in advance of resource studies and construction. In actual fact the United States is pouring millions of dollars into long range development projects, in many cases without the basic maps and resource studies that should be made in advance of investment. One conclusion only can be drawn from this. Officials really do not understand and appreciate the value of maps even though striking proofs are available.

6. The Topographic Division of the United States Geological Survey recently completed a nation-wide survey of map use. It was on a cross section or sampling basis, but broad enough to have validity. Hundreds of interviews were made, and hundreds of replies to questionaires were analyzed. Among the resultant findings one of importance is: Availability of topographic maps in advance of planning of large construction projects can result in savings as high as 3% of the total construction cost. The following example is what this means in dollars. A dam for irrigation, improvement of navigation, or power generation may cost one hundred million dollars. Three percent of this, or 3 million dollars, could be saved if adequate topographic maps were available in advance of planning and construction. Or, looking at it differently, the project could afford as much as 3 million dollars for basic mapping. The cost might be well below that figure. The important consideration here is that the maps procured for this amount will continue to save money and time for subsequent projects in the area mapped.

7. In building a section of major highway in Kentucky, map availability permitted saving enough to pay for one mile of super-highway, no inconsiderable sum. Many states in the United States have such keen appreciation for the need of maps that they supply half the funds required for preparing statewide coverage of standard quandrangle maps. Only recently Ohio entered into a cooperative program of modernizing its maps and half of the state's share was furnished from highway funds. Ohio recognized that the money was well spent in view of their extensive highway program. Quadrangle maps on a scale of 1:24,000, have been used successfully in preparing construction cost estimates and in lieu of preliminary surveys, and such savings may be repeated over and over again.

8. The geologists of the world are probably our most enthusiastic map users. Dealing as they do with many things only partly seen, they fully appreciate the three dimensional geometry afforded by the topographic map. The strike of a rock formation is easily determined by connecting plotted locations of two or more outcrops of the same formation, and dip may be computed from three plotted positions of a formation outcropping at different altitudes. The volume of mineral reserves can be established with a minimum of field work when adequate topographic maps are at hand. Geologists always ask for a map when beginning a study, ask for aerial photos to use in the field, and require a map for the presentation of the study.

9. The United Nations has recognized the value of maps to developing nations in a forceful introduction to its publication on World Cartography; by its organization of a Cartographic Division; in its sponsorship of many regional conferences on Cartography; and in its aid to training selected candidates from developing nations in special cartographic schools.

10. A correlation between the need for and value of maps in national development is shown by the fact that all highly industrialized nations are well mapped, and have a continuing program of revising or remapping at larger scales. Examples are England, France, Germany, Holland, Japan, and Switzerland. This acceptance of the need for maps, and the need for continual updating of existing maps is the best argument for the position that development would have been better managed and with fewer mistakes if mapping had preceeded it. It is this realization of need that caused such nations to put mapping at the head of activities to be undertaken in support of development.

11. Space does not provide for a voluminous listing of the great examples of waste which have been caused by lack of maps, and probably many will never be known, but a few examples will show their magnitude: 1) The huge irrigation dam so located in relation to the land to be irrigated that only the top 2 meters of stored water could be drawn off. 2) Damaging washouts and grade erosion of expensive highways built with inadequate facilities to handle flood water because the area of drainage basins was unknown. 3) The construction of costly mineral reduction facilities where necessary water and power proved impossible to provide, or where transport of materials was uneconomical because of distances and grades. I believe that a careful recording of such errors would show that the money so wasted would more than pay for reconnaissance mapping of the remaining unmapped land areas of the world.

12. The variety of base-map and map-substitute material which can be obtained is considerable. The selection of the optimum material is a technical problem best solved by conference between map user and map maker. To simplify presentation in this paper the types of maps needed for development planning are divided into four categories: 1) engineering topographic; 2) standard topographic; 3) reconnaissance; and 4) regional planning.

13. In the first group are placed all topographic contour maps at scales of 1:5,000 or larger, especially those maps designed and used in the construction of dams, power plants and industrial complexes. Such maps, with extremely high horizontal and vertical accuracy can cost many hundreds of dollars per square kilometer. This is caused by the required density of both horizontal and vertical control, the greater number of photographs, the map content and detail, and the need for extremely high relative accuracy. They are not needed for extensive areas and usually are obtained only when actual construction is assured. The engineering map is, of course, a must in the detailed planning, cost estimating and actual construction so its cost is always charged against construction.

14. In the second group (standard topographic) are placed maps at scales of 1:10,000 to 1:50,000. These are of coordinated quadrangle series type on scales ranging from 1:25,000 to 1:50,000 with contour intervals of 5 to 10 feet and accuracy on the order of the standard series of the United States, England, etc. Costs of this type of map vary considerably, depending on location, type of terrain vegetal cover and density of culture but a round figure of $00 per square kilometer (exclusive of primary geodetic control) can be used. Procurement of complete coverage of these maps in advance is advisable, but in view of the cost and time required for preparation, it is generally recommended that this type of mapping be performed only where earlier studies indicate an over-riding need. In the United States, as of 1960, the time interval required, from initiating contracts for photography to publication, was between 3-1/2 and 5 years. Obviously where the lead

time for the mapping is slight, or non-existant, it is foolhardy to begin such a program concurrently with the collection of data on mineral resources, water, soils, etc.

15. The third category, reconnaissance, includes the number of less accurate and less expensive products such as mosaics, controlled or uncontrolled, and planimetric maps or topographic maps in the 1:100,000 - 1:250,000-scale range. They are based on geodetic control which provides reasonable relative accuracy but not necessarily high absolute accuracy. Another advantage of these types of maps, for use in undeveloped areas, is the speed with which they can be compiled. The reconnaissance type product therefore appears the best solution to the map problems of the under-developed area. While costs vary with size and location of the area it is a safe assumption that small-scale photography (1:70,000) suitable for mosaic or map compilation, and by way of enlargements, for use in the field, will not cost more than $2 per square kilometer. Hiran electronic control suitable for holding extensive areas in relatively good horizontal position should not be more than $3 per square kilometer. Controlled mosaics at 1:50,000-scale might be made from these photographs at a cost not exceeding $2 per square kilometer. Reconnaissance topographic maps at 1:100,000-scale with 25 meter contours can be made of selected areas using the horizontal control developed for the mosaics. Costs will vary through a considerable range depending on local labor costs but in no case should exceed $6 per square kilometer.

16. The fourth and last category contains the regional or planning maps. Usually at 1:500,000 or the millionth-scale, they are useful in presenting overall relationships. This type of map is now generally available throughout the world. It is rarely the direct product of original surveys. This type of map was originally based on astronomic fixes, explorer's notes and sketches, and the earlier geographic attempts of small political entities. During the second World War there was a mammo th effort made to revise or compile such maps directly from aerial photography. In fact, the Trimetrogon system of 3-camera photography and compilation was designed with this in mind. Now such small-scale maps are more likely made by reducing and combining large-scale maps.

17. A coordinated mapping plan for a large under-developed, unmapped area should involve some or all of the following steps: 1) aerial photography; 2) geodetic control; 3) preparation of preliminary or reconnaissance maps; 4) preparation of a coordinated topographic map series (when and where needed); 5) preparation of engineering maps for design and construction.

18. After considering the cost of aerial photography, control, reconnaissance type and engineering maps, how can we choose between them? Perhaps the following criteria will help: 1) The selection must be between standard accuracy and expediency. A reconnaissance map in hand is worth ten standard maps in the making. One justifiably deplores the construction of maps with content or accuracy below those required for a map that will be adequate, except for revision of culture, for many years but we must recognize the urgency of providing earth scientists with adequate map bases upon which they can work today. There is a large area of misunderstanding between map users and map makers regarding accuracy and content. The geologist and the soil scientist require many identifiable positions with relative accuracy of position of 50 to 100 feet, and of elevation to 50 feet. The map maker usually translates these requirements in terms of absolute position and elevation on the earth's surface with the result that costs and preparation

time skyrocket because of the needed control. It should be remembered that a map with high relative accuracy can be produced much more cheaply than one with high absolute accuracy. 2) The time available. Mapping a large area by classic ground methods requires a large force and many months of field work. Aerial photography is a must but even in this rapid phase timing is important. In many areas weather is so critical a factor that a few days lost might cause a years wait for good photographic weather. Use of electronics is speeding up the control phase but in this area also there is a choice. Airborn equipment is adequate for reconnaissance-type maps but slower moving ground equipment is still needed for the standard-type maps.

19. It is most probable that problems concerned with soils, water, land use and mineral resources will be screaming for attention immediately. If this is the case, then aerial photographs will be required at once. Aerial photographs are the best and most rapid collectors of earth-surface data known today. They are probably, on a unit basis, the cheapest. In addition to being a permanent record, and one from which data can be recovered quickly and transferred to other media, they serve as the best media for recording field observations. Owing to recent improvements in aerial camera lenses it is now possible to photograph large areas economically at scales between 1:70,000 and 1:100,000, obtaining at one time photographs lending themselves to reconnaissance mapping and also to enlargement to the vicinity of 1:20,000-scale for photointerpretation, and use in the field.

20. With careful planning the amount and type of control needed for the mapping can be obtained at the same time as photography. Actually some types of airborn electronic equipment such as Shoran and APR are designed to be used in the photographic airplane.

21. Lack of basic data can, and has resulted in wrong assumptions, leading in turn to expensive errors in planning. Therefore it is the thesis of this paper that all of the mapping tools are at hand for our use in development programs. All that is now required is the decision to apply them. Adequate maps should be available in advance for use in the fields of geology, hydrology, soils, agriculture, forestry, transportation, resettlement, etc. It is also recommended that the reconnaissance type map comes closest in terms of overall usefulness, cost, and time available for preparation. Considering the savings in construction costs plus additional savings in resource surveys, at least the first 5% of funds alloted to development projects should be assigned for aerial photography and mapping. These recommendations are made with the knowledge that both industrial and agricultural development must be founded on accurate data about availability of raw materials, power, transportation, markets, extent and type of soils, rainfall, stream flow, and groundwater. They are made in the knowledge that impact programs are usually considered more important and in spite of the pressure for immediate programs to feed and care for hungry, ill and illiterate peoples.

22. Finally, let us consider capacity for map preparation. It is no paradox that less developed countries are the poorest mapped. They usually have fewer persons educated in mapping who are capable of designing, planning and directing a mapping program; and less financial backing for purchase of required equipment. On the other side of the coin they usually have an intense desire and national pride in doing such things themselves. Organizing, training and equipping a national organization may well take more years than are available. It appears clear, therefore, that the best and most rapid method for obtaining necessary photographs and maps is by use of well established

government agencies, commercial firms, or combinations of the two. Every effort should be made to introduce nationals of the country into all operations but this training aspect should not be allowed to delay delivery of the basic maps.

23. The extremely under-developed area in the Northeast of Brazil is presented as an example of how to proceed in a program such as this. It is practically unmapped; about one-half is covered with photographs at scales making map compilation expensive; it has a skeleton of primary horizontal and vertical control over about two-thirds its area; studies in the minerals, irrigation, ground and surface water and soils use fields have already started; it is large (almost 2 million square kilometers); it does not have good ground transport; there is illiteracy, hunger and illness there; a dynamic improvement is needed in less than 5 years.

24. The Superintendency of the Development of the Northeast (SUDENE) and United States Agency for International Development, Brazil (USAID/Brazil) are negotiating the following 5-year mapping plan, which is estimated at 7.2 million dollars - somewhat less than 3% of the joint funds earmarked for development in that area.

25. The plan contains the following main targets which can readily be identified with recommendations in this paper. They are: 1) obtain complete photo coverage at 1:70,000-scale in 4 years; 2) provide Hiran control for the uncontrolled portion of the area; 3) prepare controlled mosaics of the whole area; and 4) prepare 1:100,000-scale topographic map-manuscript over a selected one-third area.

26. The photography and Hiran control will be obtained on contract. The preparation of mosaics and maps will be partly by contract and partly by using existing Brazilian government facilities where training programs are already underway. The mapping will probably be performed in the same manner.

27. The scientists and technicians involved in the efforts depending on maps for basic data are firm in the conviction that this mapping program, if carried through, will expedite their work and contribute to the accuracy of the decisions made, as well as provide many economies in their operations.

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AEROGEOPHYSICS AND ITS ROLE IN MINERAL EXPLORATION

by L. W. Morley

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1. Introduction

(a) In trying to foster exploration and assess possibilities of mineral occurrences in areas in which there has been little or no prospecting and where geological information is sparse, governments are faced with the decision of whether or not to sponsor apparently expensive aerogeophysical surveys. The methods are powerful but they do not stand alone. It is not enough to sponsor aeromagnetic or airborne E.M. surveys, thinking that by so doing potential mines are pinpointed. Aerogeophysical surveys do not find mines, they find anomalies on which extensive ground follow-up work of several kinds must be performed before they can be considered worth drilling. A very small percentage of interesting anomalies actually become producing mines. Governments sponsoring aerogeophysical surveys should, therefore, regard such surveys as only small, but important links in the process of finding and proving ore. Provision should be made for all the other associated costly work which should come both before and after such surveys.

(b) In an attempt to view aerogeophysical surveys in their correct sequence and cost setting relative to the other associated exploratory work, Table 1 is presented as an exploration program of the type undertaken[a] by the larger Canadian mining companies operating in Canada. This program is oriented towards exploration for metallic sulphide and magnetic iron deposits because it is these types of deposits which are most susceptible to aerogeophysical methods. In prospecting for other minerals, there would therefore be less emphasis on aerogeophysics. By exploration, in this paper, is meant work directed towards the discovery of orebodies not immediately associated with known productive deposits. There will, no doubt, be wide differences of opinion not only about the details of the program in Table 1, but indeed about the wisdom of the whole concept. It serves its purpose in this paper, however, merely by providing a basis for discussion.

2. Explanation of Table 1

(a) In the construction of Table 1, the job of systematically exploring a 5000 square mile area is envisaged. This is about the minimum-sized block to which such a comprehensive program could be efficiently applied. The work is subdivided into 13 steps, each step representing a different type of work. The program could be completed in two or three years or stretched over a longer period.

(b) The main purpose of this table and in fact of the paper is to point out that in an integrated program of this nature, all the steps should be performed in a planned sequence, so that the results of one step may be used in performing the next. Lack of planning can often result in devastating loss of efficiency. Furthermore, no one step should be undertaken without having made provision for the steps to follow. Although such work would not be wasted, it would mean that money would be tied up needlessly. This is a common mistake in the mineral exploration programs of both private companies and governments.

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[a] Most of the work up to step 9, at least, is presently being done by the federal and provincial governments in Canada.

(c) In broad terms, the program is designed to begin with the less costly and less detailed investigations. The first major commitment to systematic exploration takes place at step 7 and if the decision is made to go ahead, plans and provision should be made to ensure that the program will be completed. There is no major commitment to the end of step 6 because if planimetric maps are not used for mineral exploration, they can be used for many other purposes. It should be noticed that there is no narrowing down of the size of the area until step 10, the geological mapping at a scale of 1/50,000. Judicious choice should be made at this point to select the most promising areas. This is where the second major commitment is made since the cost jumps to a minimum of about $30 per square mile. However, this work and the work which precedes it is basic scientific information which is good for all time and can be used for any future exploration. It is for this reason that many governments (including the Canadian government) carry the work to the end of step 10 at public expense and leave further, more financially risky work to private enterprise.

(d) The final detailed part of the program from step 11 to step 13 has been termed "saturation prospecting"[b]. If no mineral deposits are found as a result of applying such a procedure, it does not mean that no deposits exist in the area, it simply means that every known method has been applied and that further exploration money might better be spent elsewhere (or not at all). It is at stage 11 where the decision maker must exercise his most critical judgment. Not only must he select the area for intensive investigation, he must also decide on whether or not to use airborne E.M. and if so, what kind he should use, because there are at least 15 different instruments available and all have different capabilities in different situations. Similarly at step 12 in ground geophysical follow-up work, he must select the type of survey that has the best chance of verifying or modifying his conclusions. His most critical selection, however, is that of the location for diamond drilling, for at this point the whole program is successfully, or unsuccessfully, concluded.

(e) Another and perhaps the most important aspect of the principle of beginning with the less costly procedures, is that the easily-found mines may be discovered in the early stages so that discovery costs would be reduced.

(f) The reason 1/50,000 aeromagnetic mapping is placed before 1/250,000 geological mapping is that the results of the aeromagnetic survey can be used to great advantage in interpreting the geology at 1/250,000, as well as being used later to aid the 1/50,000 geological mapping.

(g) The location of magnetic iron deposits, if any exist in the area, takes place as a direct and automatic result of the 1/50,000 aeromagnetic surveying. But while the finding may be much less costly than for base-metal deposits, the problems of the nature of the ore, its grade, means of transportation and markets are much more critical.

(h) The cost of aerogeophysical surveys is less per line mile for large blocks. Savings in this respect reach a maximum at about 30,000 line miles depending upon the distance the aircraft is being operated from its home base. If work planned is less than this mileage for a single job, it is worthwhile attempting to share an aircraft with another organization or country working nearby. Another way of reducing costs is to combine an aeromagnetic survey with an airphoto survey. When the cloud ceiling is not high enough for aerial photography, the aircraft can be used for low-level aeromagnetic work. Planimetric maps made from the airphotos are not required until compilation of the aeromagnetic maps is started. Aeromagnetic flying can be done directly from airphotos.

(i) Planimetric maps and preferably controlled mosaics constructed from these maps should be made prior to compilation in systematic aeromagnetic mapping at a scale of 1/50,000. It is possible to work directly from aerial photographs or use uncontrolled mosaics as base maps, but such procedure invariably leads to later difficulties often involving complete recompilation of geophysical data when proper maps do become

[b] Symposium on Saturation Prospecting, Canadian Mining and Metallurgical Bull. Jan. 1959.

available. The cost of such maps should not be charged against mineral exploration alone, because such maps find extensive use in dozens of other fields.

(j) Aerogeophysical surveys can be made for certain purposes using electronic navigation without the use of airphotos or planimetric maps. Electronic navigation may be adequate for oil surveys where anomaly sources are buried perhaps 5000 feet, but in mineral surveys anomalies must be accurately located with respect to nearby geographical features. To accomplish this properly planimetric maps or photo mosaics should be used.

3. The role of the prospector

(a) Is it necessary to spend so much money to find mines? Throughout history, and even today, prospectors find mines with few aids and much smaller budgets. However, in areas where surface prospecting has been done for many years, a prospector's chances of success are poor because surface showings have long since been investigated. This is seldom the case, however, in mountainous areas, which are not as readily accessible. Because of their high relief, combined often with heavy tree-cover, there are usually many more hidden outcrops than in comparable areas of low relief. Furthermore, aerogeophysical methods are not as effective in mountainous terrain as in terrain of low relief, because it is not possible to fly close to the ground - a necessary procedure in aerogeophysical prospecting.

(b) Modern prospectors, like their old-time counterparts, possess an important characteristic. They know what they are looking for and are not side-tracked by scientifically interesting rock formations and geophysical or geochemical theories and instruments. Yet they are efficient in the use of airphotos, have adequate knowledge of geology, can use simple geophysical instruments and are familiar with simple geochemical testing procedures. Thus, in unprospected areas with good rock exposures, the cheapest way to find a mine is to encourage surface prospectors. On the other hand, in well-prospected areas, the only way to make discoveries is by use of modern methods. Step number A is inserted in the table conditional upon whether or not the area has been previously prospected on surface. If undertaken, such a program should run parallel to the main program in Table 1. The cost of $20,000 per year is, of course, dependent upon terms granted the prospectors. Many prefer to receive nominal wages with a chance to share in the profits of a discovery.

4. Description of aerogeophysical methods

Aerogeophysical methods and their underlying principles, instruments and survey procedures have been abundantly described. Table 2 gives a brief resume of the three methods.

5. Organization and Training of Personnel

No facilities exist for the training of personnel in the operation, compilation and interpretation of aerogeophysical surveys although it has been suggested that a training centre be set up under the auspices of the United Nations[c]. At present, the only way of training personnel is to purchase equipment and to employ specialists from aerial survey companies or through the United Nations to instruct these personnel. A man with university training in geophysics should be put in overall charge of an aerogeophysical unit. An electronic engineer or well-trained technician should be employed to supervise the installation and maintenance of the instruments. He can in turn instruct less-qualified technicians in the operation and maintenance of the equipment. Whether the unit is operated under the administrative authority of a geological organization or not, certainly it is a geological organization which should be responsible for planning the work of a unit and integrating it into an overall mineral exploration program. Whether or not it is worthwhile for a country to set up its own aerogeophysical facility for mineral exploration depends upon the size of the mineral potential areas. It would not seem worthwhile for a government to do this unless there were at least 10 years of continuous work for the unit to perform. This would correspond to an area of at least 100,000 square miles.

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[c]United Nations: Proceedings of the United Nations Seminar on Aerial Survey Methods and Equipments, Mineral Resources Development Series No. 12, p. 16, 1960.

TABLE I. A HYPOTHETICAL MINERAL EXPLORATION PROGRAM FOR AN UNEXPLORED AREA OF 5,000 SQUARE MILES

(oriented towards metallic sulphide and magnetic iron deposits)

PHASE	STEP NO.	TYPE OF WORK	AREA (Sq. Mi.)	COST Thousands Can. $	COST Per Sq. Mi. Can. $	PURPOSE OF WORK
PARALLEL PROGRAM	A	GROUND PROSPECTING	5,000	10 - 20 per year	2.00 - 4.00	To locate surface showings in areas of outcrop. Should be run parallel to main program.
BROAD	1	AEROMAGNETIC RECONNAISSANCE	5,000	2 - 3	0.40 - 0.60	To determine extent of area covered by igneous and metamorphic rocks and to delineate sedimentary basins and broad formations of volcanic and ultrabasic rocks.
RECONNAISSANCE	2	BROAD GEOLOGICAL RECONNAISSANCE	5,000	10 - 20	2.00 - 4.00	To map rock types along easily accessible routes such as roads, rivers and lakeshores.
SYSTEMATIC PLANIMETRIC MAPPING	3	AERIAL PHOTOGRAPHY 1/50,000	5,000	20 - 30	4.00 - 6.00	This phase should not be charged against mineral exploration alone since the maps will be used for development planning and several other types of resource surveys. (Many governments proceed directly to the construction of topographic maps without making less costly planimetric maps first.)
	4	GROUND CONTROL	5,000	10 - 15	2.00 - 3.00	
	5	PLANIMETRIC COMPILATION 1/50,000	5,000	10 - 15	2.00 - 3.00	
	6	CONTROLLED MOSAICS 1/50,000	5,000	2 - 3	0.40 - 0.60	
SYSTEMATIC AEROGEOPHYSICAL	7	AEROMAGNETIC MAPPING 1/2 mile spacing, 1,000' elev.	5,000	50 - 75	10.00 - 15.00	To aid geological mapping by tracing hidden contacts of rock formations of contrasting magnetic properties and to locate magnetic iron deposits
	8	RECONNAISSANCE GEOLOGICAL MAPPING - 1/250,000	5,000	25 - 30	5.00 - 7.00	To map groups of rock formations and geologic structure thus providing clues to the location of ore deposits.
GEOCHEMICAL AND GEOLOGICAL MAPPING	9	GEOCHEMICAL RECONNAISSANCE 1/250,000	5,000	20 - 30	4.00 - 6.00	To chemically analyse stream sediments, surface waters and rock samples for Cu, Pb, Zn content thus delineating most likely areas for deposits.
	10	GEOLOGICAL MAPPING 1/50,000	600	18 - 70	30.00 - 117.00	Same as (8) except subdividing mapped groups further and showing more detailed structure.
DETAILED EXPLORATION	11	DETAILED AEROMAGNETIC AND ELECTROMAGNETIC 1/8 mile spacing 300' elev.	150	40 - 60	266.00 - 400.00	Detailed mapping of magnetics and searching for conductor systems. Such anomalies could be caused by metallic sulphide deposits.
	12	GEOPHYSICAL GROUND FOLLOW-UP	50	40 - 60	800.00 - 1,200.00	Verifying existence and exact location of airborne anomalies on ground and to measure anomalies by other geophysical methods.
	13	DETAILED GEOLOGICAL MAPPING, GEOCHEMICAL TESTING, EXPLORATORY DRILLING	50	300 - 400	6,000.00 - 8,000.00	Mapping detailed geological structure in order to determine best drill location and angle of holes. Geochemical testing to check anomaly is caused by metal deposit.
POST-PROGRAM	Z	DRILLING TO PROVE UP OREBODY		?	—	

TABLE 2. SUMMARY OF AEROGEOPHYSICAL METHODS

METHOD	ROCK PROPERTY MEASURED	DIRECT INDICATION OF (direct prospecting)	VALUE AS AID TO GEOLOGICAL MAPPING (indirect prospecting)	MANY MISLEADING ANOMALIES CAUSED BY	PENETRATION	INSTRUMENTS AVAILABLE COMMERCIALLY	COST OF INSTRUMENTS AND INSTALLATION	NUMBER OF PERSONNEL IN ADDITION TO FLYING CREW
AERO-MAGNETIC	Intensity of magnetization approximately proportional to per cent magnetite in rock	Magnetite deposits. — Pyrrhotite deposits - but may be confused with deposits of disseminated magnetite	Good	Disseminated magnetite and barren pyrrhotite	Unaffected by overburden, but poor through thick lava flows	Fluxgate - no Proton - yes	$30,000 - $50,000	1 geophysicist 1 electronic technician 2 operators 10 compilers
AERO-ELECTRIC	Electrical conductivity mostly caused by sulphides of iron, copper and lead and by graphite	Massive metallic sulphide deposits	Poor	Barren metallic sulphides. Abundant graphite occurrences. Saline overburden	0 - 400 ft. decreases with increase in conductivity of overburden	Several	$30,000 - $50,000	1 geophysicist 1 electronic technician 1 operator 2 compilers
AERO-RADIOMETRIC	Natural gamma ray activity of uranium, thorium and potassium-40 on surface of ground	Uranium	Limited (not generally used)	Large outcrops of granite containing disseminated potassium-40, thorium and uranium	Nil — Gamma rays absorbed by water and overburden	Several	$5,000 - $10,000	1 operator 1 compiler

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ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.5.1

Canada

MINERAL DEVELOPMENT POLICY

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Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

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MINERAL DEVELOPMENT POLICY

by

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Introduction

1) The development of a nation's mineral resources is an unending challenge calling for close co-operation between government and private industry. Under the free enterprise system both the public and the private sectors have functions that are essential to the orderly and continuous growth of a healthy mining industry.

2) Government must supply the base maps from which an intelligent prospecting or exploration program can be organized; it must establish regulations under which title may be obtained and mineral deposits exploited; it must provide the laboratories and scientists necessary to promote processing and testing of minerals; it must devise an educational system designed to provide scientists, engineers and prospectors to serve the industry; it must provide the stable political climate and equitable taxation policies necessary to encourage the investment of capital required to develop the nation's mineral resources.

3) Private industry must supply the knowledge and capital to explore, develop and exploit the mineral deposits. These activities in a particular area will probably exceed in detail the scope of government programs. As will be pointed out, the experience of developed countries, such as Canada, can be drawn on as a guide to assist planning and regulation.

4) Although Canada is a relatively young nation, 5 years from its 100th anniversary, its mining industry is well developed and Canada is the world's foremost exporter of mineral products. The value of its mineral production in 1961 was 2,575 million dollars. Canada is the free world's largest producer of nickel, asbestos and platinum and it is second in uranium, cadmium, gypsum and titanium; third in aluminum, zinc, gold, cobalt and bismuth; fourth in silver, magnesium, barite and lead; and fifth in copper. Minerals and mineral products account for 40 per cent of all revenue freight traffic within Canada and have been responsible for the construction of 1,343 miles of railway since the end of World War II. Minerals and mineral products provide 40 per cent of all Canadian exports.

Minerals Jurisdiction

5) Under the federal system of government enjoyed by Canada, all mineral rights, with the exception of those in the federally-administered Yukon and

Northwest Territories, Indian reservations and National Parks, are vested in the various provinces of Canada, of which there are ten. This situation has its origin in the British North America Act of 1867. Excepting Prince Edward Island, which has no mining industry, all provinces of Canada have their own mining acts and other pertinent legislation through which the provinces administer and regulate the mineral industry within their boundaries. Mineral exploration, development and production in the Yukon and Northwest Territories are under the jurisdiction of the federal Department of Northern Affairs and National Resources.

6) A basic requirement for mineral development by private enterprise is security of land tenure and this has been provided by the legislation of the various federal and provincial government bodies concerned with minerals jurisdiction. The various mining acts and regulations are revised periodically to keep pace with changing conditions. Uniformity between provinces is not usually attempted or maintained and sections of the various acts vary widely. However, they all have a common goal: the most advantageous exploitation of mineral resources for both the province and the mineral industry.

7) The main purposes of the Mining Acts are the disposition of mineral rights and the provision of rules for mineral development. All the Acts are generous in that mineral rights on Crown lands can be acquired simply by staking. The right to stake is granted under a prospector's license, which may be acquired annually for a nominal sum. Canadians, other British subjects, and aliens over 18 years of age all have the same rights and privileges with respect to exploration for and development of minerals in Canada. Mining claims may be staked anywhere in Canada, except in national and provincial parks and Indian reservations, without the necessity of discovering a mineral deposit prior to staking. Once a claim is staked, the staker's rights are protected for a period of about 5 years, provided certain specified work is performed each year; assessment work requirements vary between areas although they are not particularly stringent in any area. In most cases, such activities as geological or geophysical surveys are accepted for assessment purposes.

8) If a mineral deposit is discovered on a claim, the right to proceed with extraction is granted under a long-term lease, a concession or a permit, which is renewable. In the two major mining provinces of Ontario and Quebec, absolute title to mining claims can be obtained by bringing claims to patent. The return to the provinces for the granted extractive rights takes the form of moderate royalties on production.

9) The staking of claims is historically the means by which most of the mineral rights in Canada have been acquired. However, in remote and virgin areas of Canada, where exploration is costly, large tracts of land are granted to responsible exploration groups on a permit, concession or lease basis. These grants carry exclusive exploration rights to the lessee for a specified period of time. This procedure has hastened the exploration and development of mineral resources in areas that might have otherwise remained unexplored.

10) It has been the Canadian experience that security of land tenure is fundamental to the encouragement of mineral exploration and development and to the attraction of private capital. Without security of land tenure, other inducements or incentives may be of little avail. However, when security of tenure is not only present but is accompanied by the generous disposition of mineral rights and incentive taxation and, of course, interesting geology, then mineral exploration and development may be assured.

Tax Incentives

11) Federal corporate income tax legislation provides substantial direct encouragement to the Canadian mineral industry - a three-year tax-exempt period for new mines, income tax allowances for pre-production costs, generous depletion and depreciation allowances, freedom from capital gains tax, and special excise tax and customs tariff provisions. Since the three-year tax-exempt period was first introduced in 1935, Canadian mineral output has grown in value from 313 million dollars in 1935 to the 2,575 million dollars of 1961. The three-year tax-exempt period, of course, has not been wholly responsible for this growth but it is representative of the general federal encouragement provided the mineral industry and it has played an important part in promoting its growth. Through this provision, a new mine is given the opportunity to recover, before the imposition of taxes, a large part of the capital expenditure which was necessary to achieve production, thereby according recognition to the financial risk inherent in mining ventures.

12) The federal government has provided special encouragement in certain other instances when circumstances have so warranted. An example of such special encouragement was the deep-test oil well legislation in effect during the period 1942 to 1956. This legislation provided special income tax deductions as an encouragement to extend the petroleum resources of Canada, in new localities. Federal income tax legislation was amended to encourage the exploitation of potash, and of bituminous sands, both of which Canada has in large quantity. Federal income tax legislation has recently been amended to encourage the further processing of minerals in Canada and to encourage product research. No export taxes are levied on Canadian minerals or mineral products.

13) As the British North America Act provides for both the federal government and the provinces to levy direct taxes, such as income taxes, both levels of government have endeavoured to provide similar income tax incentives to the mineral industry so that the encouragement provided by the one level of government is not decreased but is, instead, enhanced by the other level of government. This similarity of treatment is exemplified in Canadian corporate income tax arrangements whereby the federal government collects the provincial share of corporate income taxes on behalf of most of the provinces; the same incentive provisions as apply to the federal share of this tax also apply to the provincial share.

14) Royalty and mining tax provisions of the various governments are all designed to encourage exploration, in that they are virtually all levied on production or profits, rather than on ore reserves in the ground. Such levies are usually moderate and so arranged as to place a minimal financial burden on the lower profit mines. In some instances, they provide inducements to mining companies to process minerals beyond the concentrate stage within the province in which the minerals are mined. In two provinces and in the Northwest Territories, new mines are granted a three-year period of exemption from royalty and mining taxes; this benefit is in addition to the three-year period of exemption from corporate income taxes.

15) It is Canadian experience that the surest method of encouraging mineral exploration and development is by means of tax incentives, particularly those measures which permit a mining company to obtain early and complete recovery of its capital investment. Permissive recovery of capital investment gives recognition to the intrinsic risks of mineral development and provides insurance against the changing attitudes of changing governments. A detailed examination of the tax incentives used by the different levels of government in Canada might well provide developing countries with useful ideas for the encouragement of mineral exploration, development and exploitation.

Government Services

16) An important adjunct to the provision of financial incentives in Canada has been the provision of government services. The federal government provides the basic geodetic, topographic and hydrographic maps required for mineral exploration and development and amends its annual programs wherever necessary to assist the development of major new mineral discoveries. The federal government and certain of the provincial governments have well organized geological survey establishments and provide basic geological maps for exploration and prospecting. Exploration and prospecting have been, historically, the functions of private enterprise in Canada.

(a) Geological Survey of Canada The work of the Geological Survey of Canada, a branch of the federal Department of Mines and Technical Surveys in Ottawa, and the work of the various provincial geological survey establishments are complementary. The Geological Survey of Canada, which was formed in 1842 (and so predates Confederation in 1867) and which now has an establishment of 200 professionals and 200 supporting personnel, generally undertakes geological mapping on a broad regional scale. The provincial geological surveys generally investigate, in detail, the economic worth of the known mineral occurrences which appear to be of immediate economic importance and which occur on provincial Crown land. The Geological Survey of Canada is responsible for the systematic geological mapping of Canada. The Survey has moved with the times, taking advantage of all the modern advances in the fields of science; it is, today, a complex, integrated survey and research organization engaged in all aspects of the geosciences. Although its aims are scientific rather than commercial, its field program and associated laboratory investigations are designed to benefit, now and in the future, those engaged in mineral exploration and development. The Geological Survey's prime task of mapping and interpreting the geology of the country is essential to the orderly and efficient development of Canada's mineral resources. Any country which has yet to develop its mineral resources could profit considerably from a study in detail of the development, organization and procedures of the Geological Survey of Canada. Immediate advantage could be taken of the strides made by the Survey in modern techniques in the field and laboratory. Of particular significance in exploration techniques in recent years has been the use of helicopters, the Piper Super Cub, and aerial geophysical surveys. Through the use of large, low-pressure tires, the Super Cub can be used to land geologists in areas to be surveyed regardless of the roughness of the ground. From the year 1952, when the Survey first used helicopters, to the present, more of Canada has been mapped than was done in the 110 years prior to 1952. During this period, the aeromagnetic maps obtained from aerial geophysical surveys have become an integral and essential part of the Survey's regional mapping programs. The results of the work of the Geological Survey of Canada are made available through the regular publication of geological, geophysical and geochemical maps and reports. These reports and maps are of great importance and value to mineral exploration companies in Canada.

(b) Mines Branch The federal government and some of the provincial governments provide such specific services as free mineral analyses to prospectors, grubstake or prospectors' assistance programs, educational courses for prospectors, and ore dressing research. For instance, the flow sheets for all Canadian uranium mines were developed in the laboratories of the Mines Branch of the federal Department of Mines and Technical Surveys. The Mines Branch, first formed in 1907 out of part of the Geological Survey of Canada, has evolved into a complex research organization with an establishment of approximately 400 engineers and scientists and 250 supporting personnel. The Branch's chief purpose is to serve the mineral industry through research. It is engaged in applied research and technical services to assist the mineral industry and other government organizations in

solving immediate problems related to minerals, metals and fuels and it is also engaged in fundamental research in anticipation of the future needs of the mineral industry. The Mines Branch has no parallel in the provinces, although two or three of the provinces undertake applied ore dressing research through their own mines departments or provincial research foundations. Increasingly, the Branch is encouraging the provinces and industry, with some success, to undertake more applied research so that the Mines Branch laboratories may concentrate more on fundamental, national, long-range mineral research projects. Although the establishment of well-equipped, adequately staffed minerals research laboratories may well be beyond the resources of less developed areas, in the early stages of development, the establishment of a small scale laboratory devoted to analytical and simple ore dressing work should be given early consideration. It is from such small beginnings that the Canadian Mines Branch laboratories grew; during the half century that the Mines Branch has been in existence most, if not all, mining companies in Canada have benefitted substantially from the services provided by these laboratories.

(c) Mineral Resources Division This unit of the federal Department of Mines and Technical Surveys is engaged in mineral resource and mineral economic studies. The Division also has no counterpart in the various provinces, although one of the major mining provinces has recently formed the nucleous of a group to make studies in the resource-economics field. The federal Mineral Resources Division was formed in 1886 in the Geological Survey of Canada and it remained an integral part of either the Geological Survey of Canada (1886-1907) or of the Mines Branch (1907-1956) until 1956 when it became an independent operating unit of the department. The Division now has an establishment of 30 professionals and 24 supporting personnel. In its early years the Division had two main functions - the detailed geological examination of specific mineral deposits and the collection, compilation and publication of mineral statistics. The work of the Division now lies in the mineral resources, mineral economics, mineral legislation, mineral-taxation, and governmental administration fields rather than in scientific laboratory research or detailed field surveys. It advises senior departmental and other governmental officials on matters affecting Canadian mineral policy. It carries out technical-economic and legislative studies on all phases of the Canadian mineral industry; it administers the government's cost-aid financial assistance to the gold mining industry; it arranges foreign technical aid training programs in the domestic minerals field; and it maintains extensive records on all matters pertaining to domestic mineral resources and some record of matters pertaining to foreign mineral resources. Mineral development programs, in less developed areas should include the early establishment of a small group to work in the field of resource-economics. An important contribution of this group could be the careful evaluation of all programs directed towards mineral development to ensure that available funds are expended on those programs which show the best possibility of providing economic benefit to the nation. Cost-benefit analyses are always important; they are vital when funds are limited.

(d) Aerial Photography The importance and usefulness of aerial photographs in the development of Canada cannot be overstressed. Firstly, they provide a basic tool for the Surveys and Mapping Branch of the federal Department of Mines and Technical Surveys in the preparation of the Branch's National Topographic Series of maps. Secondly, they are of direct use to industry through the National Air Photo Library first established as a reference service in 1925. This library has a file of upwards of 3 million photographs, there being one print from each aerial negative taken by or for the federal government. It would seem highly desirable for less developed countries to consider the establishment of a National Air Photo Library as a necessary first step in the launching of a minerals exploration program.

(e) Roads For some years, the federal government has followed a policy under which it provides financial assistance for the construction of roads, railroads, airstrips, power facilities, docks, harbours, and housing in connection with the development of mineral resources. For the last quarter of a century it has provided financial assistance in the construction of mine access roads, under an arrangement whereby the company pays one third of the cost of construction, the province pays one third and the federal government pays one third. During the past five years, special Northern Development Roads and Roads to Resources programs have been implemented by the federal government, the latter being in collaboration with the various provinces. In addition to federal-provincial co-operation in the provision of mine access roads, most provinces maintain their own mine access road programs as a means of encouraging exploration and development.

(f) Railroads Although virtually all railroad building in Canada since World War I has been financed out of the project responsible for rail line construction, certain special circumstances have induced governments to finance rail construction in the interest of general areal development. The 430-mile Pine Point railway, to be financed largely by the federal government, will provide long-term encouragement to mineral development in the Northwest Territories, for which the federal government has administrative responsibility.

(g) Airstrips Because of the tremendous size of Canada and the resultant isolation of many mineral developments, the federal government has an active program of airstrip construction for mining communities. This program has value both during the development phase of the project and during the active exploitation of the deposit.

(h) All these forms of assistance - roads, railroads, airstrips, docks, harbours, housing, and, more recently, telecommunications, are areas wherein a government can encourage and assist mineral development and exploitation. They have been of great importance in the development of the Canadian mineral industry and similar aids could be of substantial help in the development of a mineral industry in a less developed area.

Subsidies

17) Canada, both federally and provincially, has traditionally avoided resorting to subsidies in support of depressed mineral industries. The principle that has been followed, with two important exceptions, is that mineral enterprises must be economically viable in the legislative and commercial environment in which they operate. The two exceptions are gold and coal.

18) In the case of gold, a number of dependent communities have been built up around operating gold mines, particularly in the provinces of Ontario and Quebec. With the fixed price of gold which has existed for the past 28 years and with steadily rising operating costs, the higher-cost mines - and, hence, their dependent communities - have been assisted for the past 14 years by the federal government's Emergency Gold Mining Assistance Act. This Act provides financial assistance, on the basis of operating costs, to higher cost mines. In 1961, lode gold mines received a total of 12.5 million dollars assistance under this Act.

19) The circumstances involving the coal industry are somewhat similar; a number of wholly-dependent communities have been built up around the coal mines in eastern and western Canada. Distance from markets, declining markets and rising costs have aggravated the social problems of the dependent communities. The coal problem is a long-standing one of 34 years' duration and one with no easy solution. To assist the dependent communities, federal transportation

subventions are provided on the shipment of coal to central Canadian markets, for sale under competitive conditions. Within the past year, an additional small direct subsidy, on all coal shipped, has been provided to encourage sales locally within the Atlantic provinces. In the case of western Canada, transportation subventions are also provided to enable Canadian bituminous coal to compete in the Japanese market. The total financial assistance provided in 1961 through transportation subventions amounted to approximately 18 million dollars. About one third of the coal moved under subvention to markets in central Canada is consumed in federal government installations. Coal is further assisted by the Coal Production Assistance Act which provides low interest capital loans for modernization and mechanization. Coal is also assisted, indirectly, by The Atlantic Provinces Power Development Act which helps to provide low cost power, based on coal, for industrial uses in the four Atlantic Provinces.

20) The Province of Nova Scotia also assists its coal industry, and hence the dependent communities, through loans and direct financial subsidies to small coal mines within the province. The total amount of money directed in this manner by the province amounts to a few hundreds of thousands of dollars per year. These are the only direct provincial subsidies to mineral enterprises in Canada. In striking contrast to the financial assistance which Nova Scotia provides its coal industry, the Province of Alberta provides money to move miners and their families from moribund coal mining centres to places of employment elsewhere in the province. The Alberta program has been highly successful.

21) The effect of the federal and provincial government assistance programs for both gold and coal has been to provide social assistance to dependent communities in a manner which will not be harmful to other nations engaged in the production of gold and coal. However, despite the 14 years in which 156 million dollars of federal assistance has been paid for gold and the 34 years in which 170 million dollars of federal assistance has been paid for coal, the problems of the communities not only remain but they have become more intense. As the gold and coal reserves which support the dependent communities have been gradually but continuously depleted, both the population and the social capital in the communities have grown. At this particular point in time, the problems of the dependent communities are greater than they were at the commencement of the subsidies. Developing areas, when faced with the problems of depressed mining communities, should explore all possible solutions before embarking on subsidy programs. Subsidies tend to be self-perpetuating and rarely do they solve the problems to which they are applied; if they have any value it is that they alleviate immediate distress and postpone the solution of the problem until other remedial measures may be adopted.

Bounties

22) An example of the principle of encouragement to the mineral industry, both provincial and federal, has been the use of bounties, occasionally in company with, but usually in preference to, national tariffs, to foster the birth and growth of infant industries based on indigenous mineral raw materials. Bounties have been used by the provinces of Ontario and British Columbia, for specific periods of time, to promote the establishment of primary iron and steel production based on indigenous iron ore. The Ontario iron ore bounty was of concrete assistance in the development of the first low grade iron ore property on the North American continent - a siderite mine in the Michipicoten area of Ontario. The British Columbia iron ore bounty was of important assistance in the establishment of the province's first electric pig iron plant based on pyrrhotite mine tailings at Kimberley, British Columbia. In 1961, British Columbia also established a bounty on the production of blister and refined copper within the province; by this bounty, the province hopes to encourage the development of a copper smelting

and refining industry. On the national level, the federal government still provides a bounty for the use of domestic coal to produce domestic pig iron. Two producers, directly in the case of a producer in Nova Scotia and indirectly in the case of a producer in British Columbia, benefit from this bounty under the Canadian Coal Equality Act. In both these instances, there is no Canadian tariff on iron ore or on coal used in the production of primary iron and steel.

23) The use of bounties has been moderately successful in Canada, most notably where the general economic conditions surrounding a specific mineral project have been almost, but not quite, favourable. In these circumstances, the provision of a bounty has tipped the scales toward the favourable side. Bounties have had no success where economic conditions were clearly against the project. They do constitute, in certain circumstances, a useful tool for the development of infant primary industries in less developed areas.

Tariffs

24) Tariffs may also be helpful in establishing basic primary industries. Although Canadian tariffs on imported crude minerals are either non-existent or minimal, the federal government, which has jurisdiction in all tariff matters, has employed tariffs on a moderate scale to promote primary industry and to help it in its formative years. In the use of tariffs, great care should be taken to ensure that they do not become a shelter for inefficient industry.

Government Participation in Mining and Oil Enterprises

25) The present state of mineral development in Canada results almost entirely from the efforts of private enterprise operating under encouraging and incentive-creating legislation. Only rarely have any of the eleven governments become intimately involved in mineral development or exploitation. Since the exceptions have been so rare it is useful to describe them.

26) During World War II, the federal government considered it necessary to operate a small number of Crown corporations to obtain certain strategic minerals. One of these, Wartime Metals Corporation, operated tungsten, molybdenum, chromite and magnesium mines during World War II and disposed of its assets to private industry following the war. Another, Wartime Oils Limited, through loans to private operators, financed the drilling of 22 oil wells in the Turner Valley field of Alberta; 21 of these wells were successful and the project as a whole returned the federal government's capital investment. Abasand Oils, Limited, also a Crown corporation, sponsored exploratory drilling and research into the Athabasca oil sands of Alberta. Another Crown corporation, Eldorado Mining and Refining Limited, purchased, in 1944, the radium mine at Port Radium on Great Bear Lake, Northwest Territories, to continue the production of uranium used in the World War II Manhattan Project. Although the ore reserves at Port Radium were exhausted two years ago, Eldorado Mining still operates uranium mines near the north shore of Lake Athabasca, Saskatchewan, (brought into production in 1953), a uranium refinery at Port Hope, Ontario, and uranium research facilities in Ottawa, and it acts as the government purchasing agent for privately produced uranium concentrate. Its exploration and production activities are confined entirely to the strategic material, uranium.

27) On the provincial level, Saskatchewan produces and markets sodium sulphate from natural deposits at Chaplin. The Province of Newfoundland for a short period during the 1950's operated a gypsum mine and wallboard plant on its west coast; this operation has now been taken over by a private company. In the 1950's the Newfoundland government was also directly engaged in mineral exploration, an activity which has been abandoned.

28) This has been virtually the limit of direct government involvement in mineral exploitation in Canada. During 1961, the total dollar value of all production from government exploitation was about $27 million, or one per cent of Canada's mineral production - a minor percentage and one which results largely from strategic necessity. Less developed nations, as with more developed nations, have limited financial resources, whether the resources be drawn from domestic taxpayers or raised by borrowing. In such situations, there is much benefit in creating a national climate that will attract private domestic and foreign capital into mineral exploration and development, rather than in using precious public funds on such development. The benefits to Canada of employing such a policy have been tremendous, creating an industry which has proven to be a mainstay of the domestic economy.

Commissions of Enquiry into Broad Regional and National Mineral Problems

29) One of the institutions resulting from Canada's British heritage is the appointment of Royal Commissions to enquire into and make recommendations on matters of broad regional or national concern. The mineral industry has received its share of Royal Commissions at both the federal and provincial levels. The coal industry, in particular, has received more than its share with Royal Commissions having been appointed at various times by the provincial governments of Nova Scotia, New Brunswick, Saskatchewan, Alberta and British Columbia, and a total of three Royal Commissions having been appointed by the federal government. In addition, the coal industry has been the subject of numerous enquiries by Special Committees of both the House of Commons and the Senate. The Royal Commission on Canada's Economic Prospects, appointed in 1955, was responsible for two major studies of the mineral industry - one on minerals and one on energy - along the lines of the world-famous United States "Report of the President's Materials Policy Commission". The federal Royal Commission on Energy, appointed in 1957, resulted in the formation of the National Energy Board and the implementation of a National Oil Policy.

30) Although the recommendations of all Royal Commissions are, by no means, implemented in their entirety, a surprisingly large number are eventually adopted and some of those adopted over the years have brought about important developments in the Canadian mineral industry. The recommendations of the Ontario Royal Commission on Nickel in 1917, brought about the refining in Ontario of nickel produced in the Sudbury area of Ontario. In the case of the Royal Commission on Energy, the Commission recommended that the level of Canadian oil production be brought up to a certain prescribed level within a specified period of time. Although Canada's new National Oil Policy constitutes a modification of the Royal Commission targets, it has set domestic production targets for 1961 and 1963. The policy was expressed in a simple statement from the Minister of Trade and Commerce; it has not been translated into legislation. The target for 1961 was met by the voluntary and co-operative efforts of the various companies engaged in the producing and consuming sectors of the petroleum industry of Canada.

31) Commissions of enquiry do, therefore, constitute one of the sources of Canadian mineral policy, and a stimuli to mineral development particularly in areas of broad regional or national concern. In similar circumstances, they may provide a useful technique for developing nations.

Education

32) In Canada, education is constitutionally the responsibility of the ten provinces. Within the provinces, there are three basic levels of education - primary, secondary, and university. Except for supporting technicians, it is the responsibility of the universities to supply the mineral industry with trained

professional staff. Of the 47 degree-granting universities and colleges in Canada, only 20 give courses leading to degrees in one of the mineral industry disciplines, graduating about 500 new professionals per year. Canada has no university or college devoted solely to mineral industry subjects.

33) The university year, lasting from mid-September to mid-May, is ideally suited to Canadian conditions of climate which, in turn, has a considerable influence on domestic industrial activity, particularly in the mineral resources sector. The long summer recess provides students with an opportunity to earn money; to obtain practical experience; and, at the Master's and Ph.D. levels, to obtain a thesis problem. In the provision of summer employment there is complete co-operation between industry, government and the universities. The universities provide the theoretical education; industry and government provide the practical experience. Very tangible benefits accrue to all concerned.

34) Supplementing the universities in supplying trained professional staff, is one technological institute which provides a two year practical course in mineral industry trades. This institute makes a vital contribution in training an average of 50 technologists a year for useful and responsible employment.

35) In Canadian experience there are a number of elements which might warrant consideration by less developed areas. Firstly, the blending of a shortened university year with an industry field season would seem to have much merit. It would permit a marrying of theory with practice, so necessary in a developing mineral economy. It would help to weed out those unsuited to conditions in the mineral industry before too much time, effort and public money has been spent on their education. It would encourage the industry itself to take a responsible, enlightened and helpful approach towards the training of replacement engineers. Secondly, the establishment of a technological institute, at far less cost than a university or college, would make it possible to provide in one half the time a proportionately larger number of semi-professionals trained for positions of responsibility.

Conclusions

36) The attainment of a mineral industry presupposes the existence of mineral occurrences under geological conditions favourable to economic exploitation. If this situation is not present, there would seem to be little reason to spend money on exploration. If it is present, then much benefit can come from expenditures on mineral exploration.

37) .Canadian experience indicates that enlightened, consistent government policy is needed to encourage mineral exploration, development and exploitation; that the special needs of the mineral industry are best met by incentive-creating legislation; that corporate affiliations may be most useful in both the provision of capital for mine finance and the provision of markets for primary mineral output; and that a supply of trained engineers, scientists and technicians is essential to a sound and lasting mineral development program.

38) The development of a nation's mineral resources for internal use and for export is a basic means of providing new wealth. In the case of less developed countries, mineral development is a logical first step towards mineral self-sufficiency; it permits the acquisition of foreign exchange; it enables the development of technical "know-how"; and it promotes the development of related resource-based secondary industry.

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